Diffraction with CDF II at the Tevatron

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and

The CDF Collaboration

Contents

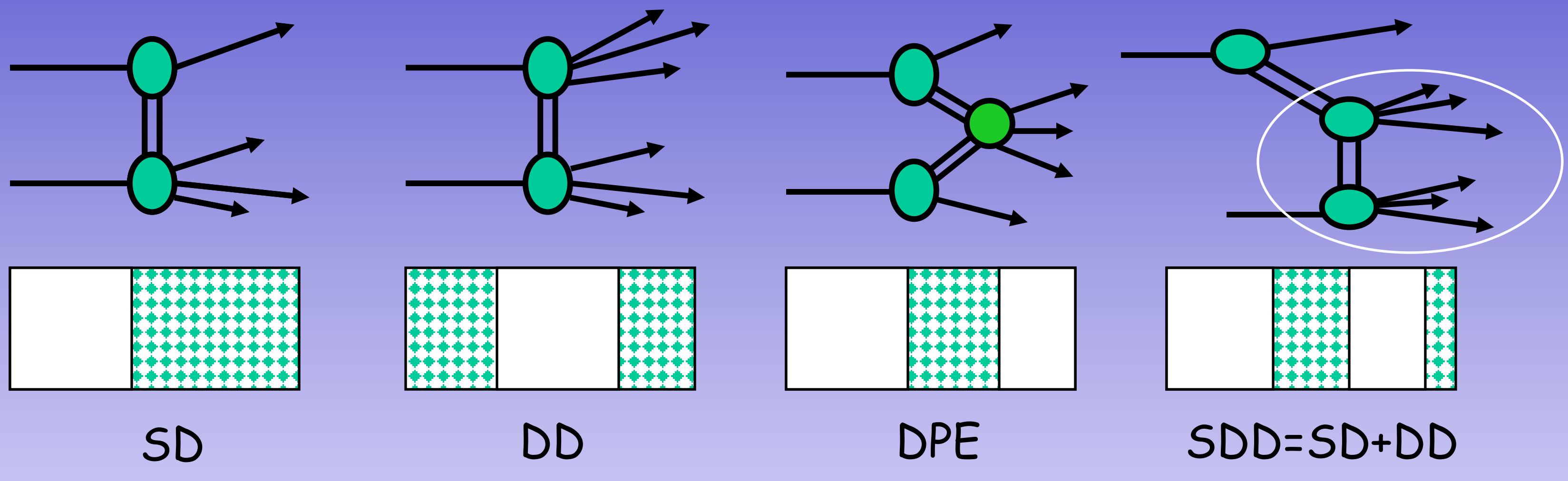
- Overview
- Diffractive W/Z
- Exclusive JJ

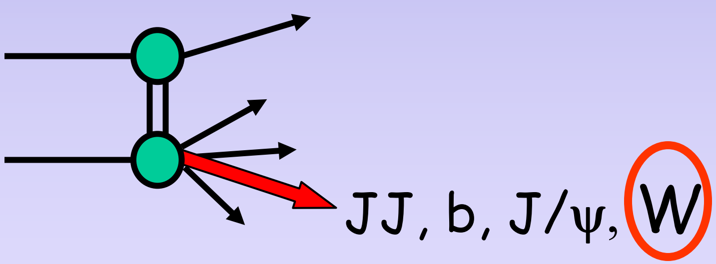
Other CDF II results in this conference:

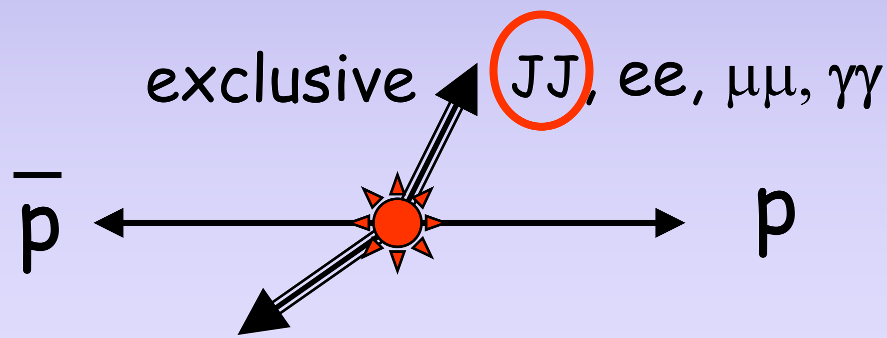
- Exclusive di-leptons and di-photons
- Rapidity gaps between (very forward !) jets

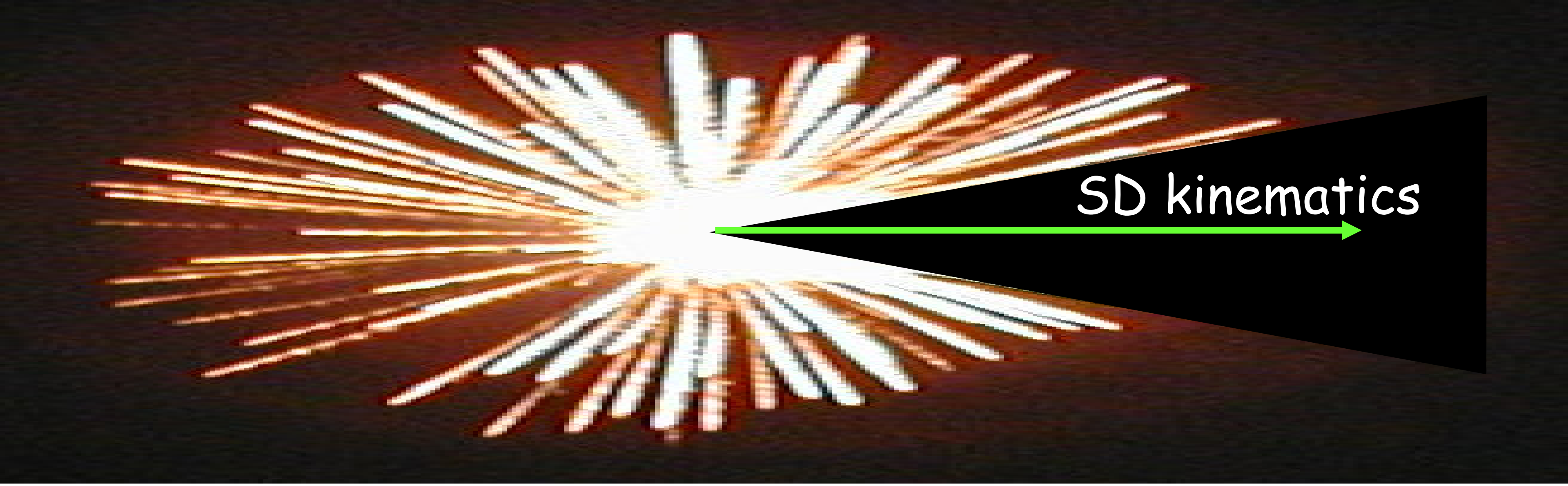
Overview

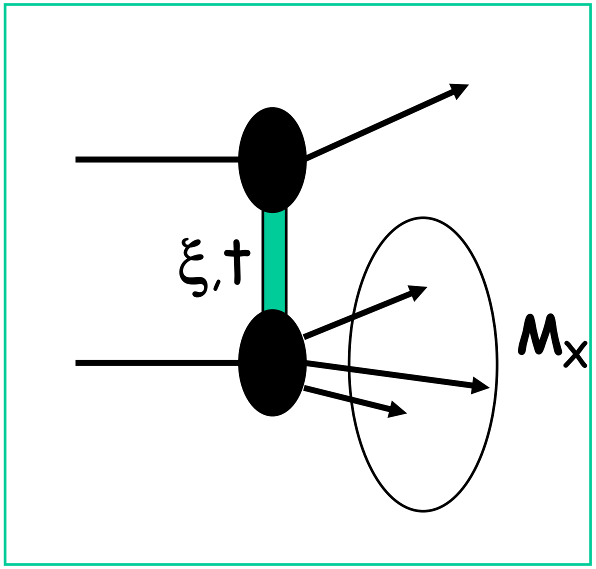
Soft and hard diffraction and exclusive processes at CDF

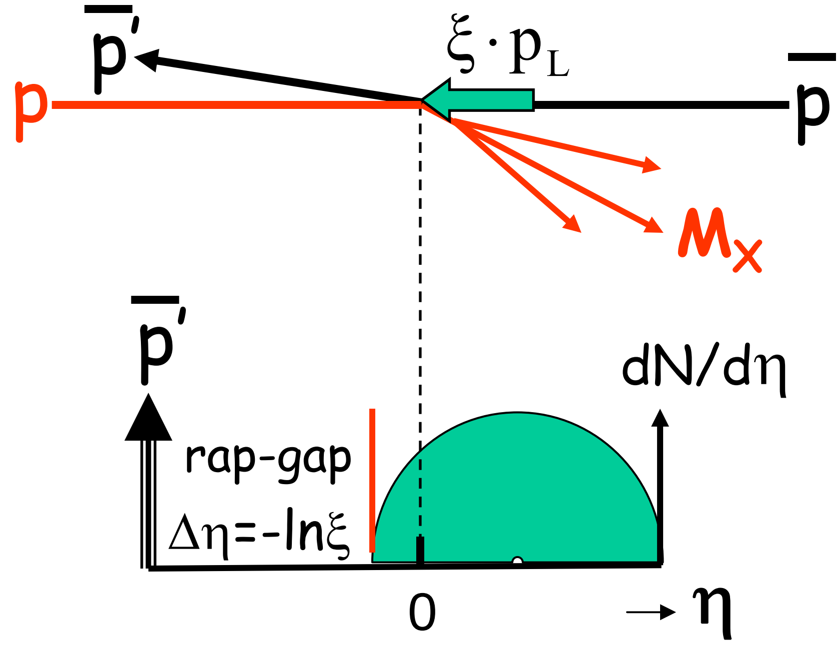




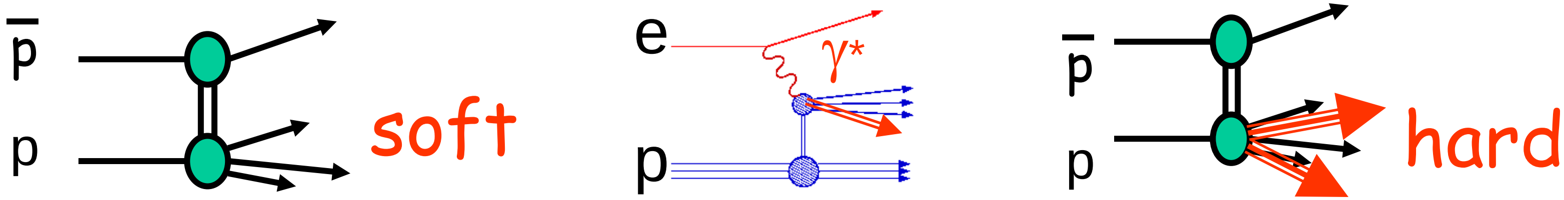


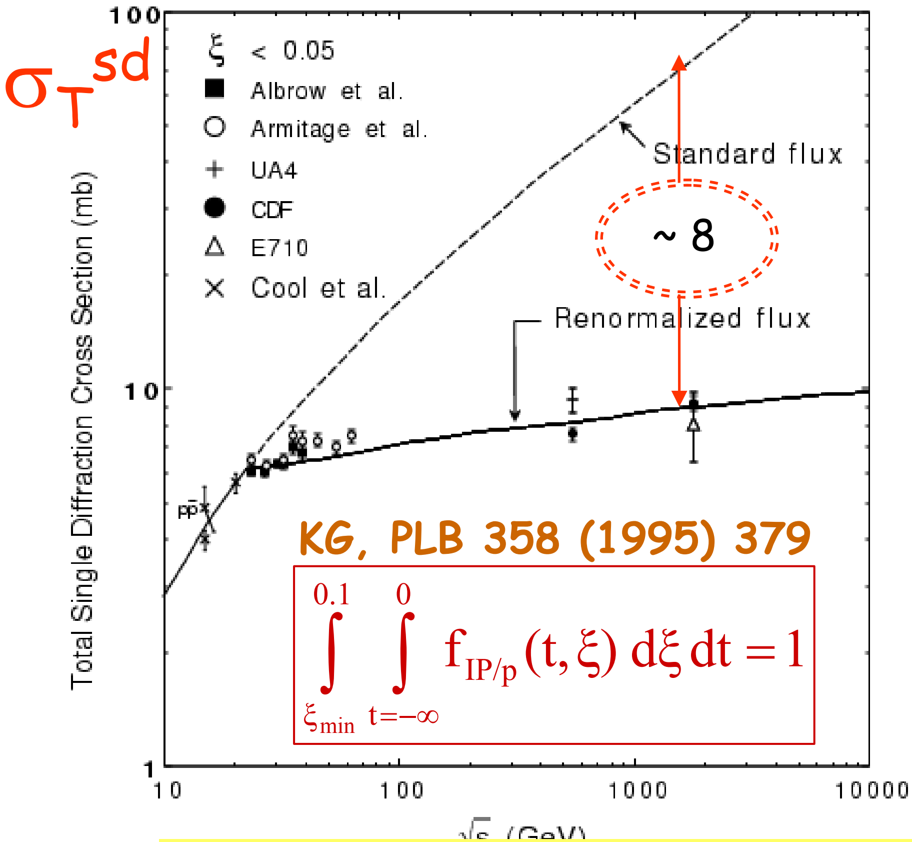

SD kinematics

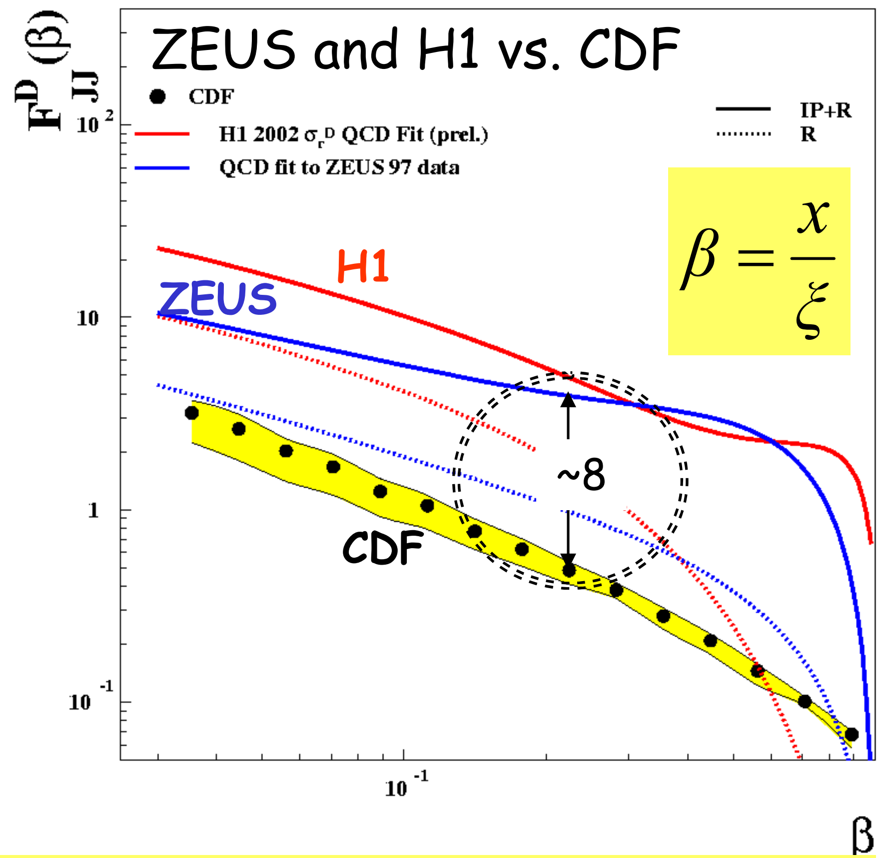

ξ,t
Mx


p̄'
ξ·pL
p
p̄
Mx
p̄'
dN/dη
rap-gap
Δη=-lnξ
0
→ η

Breakdown of factorization – Run I







Magnitude: same suppression factor in soft and hard diffraction!
Shape of β distribution: ZEUS, H1, and Tevatron – why different shapes?

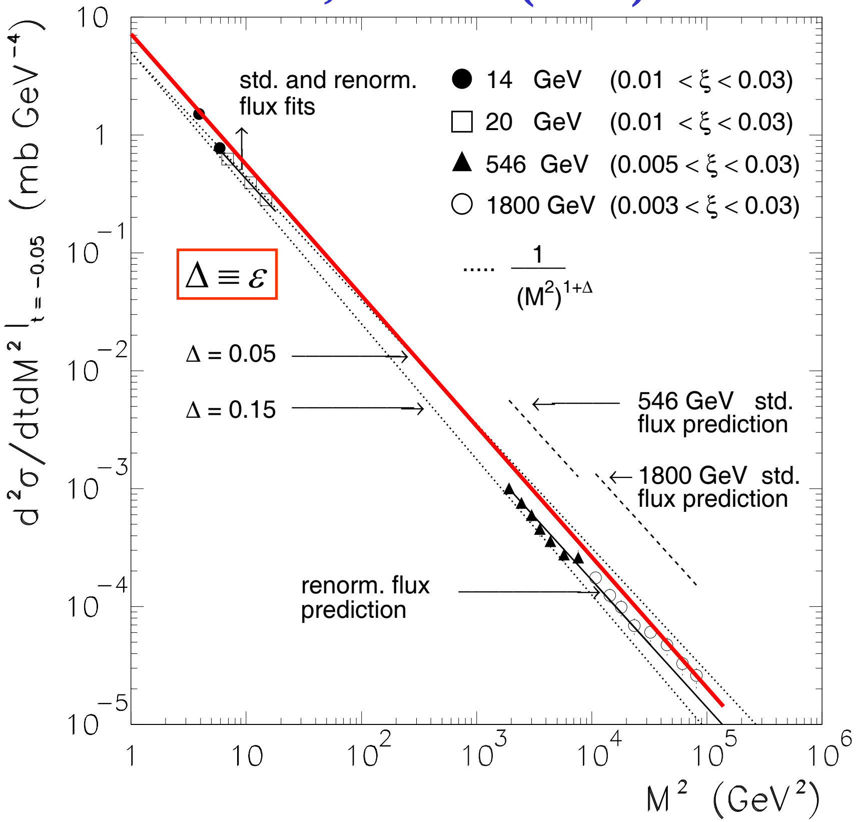
M^2 scaling - Run I
$d\sigma/dM^2$ independent of s!

renormalization

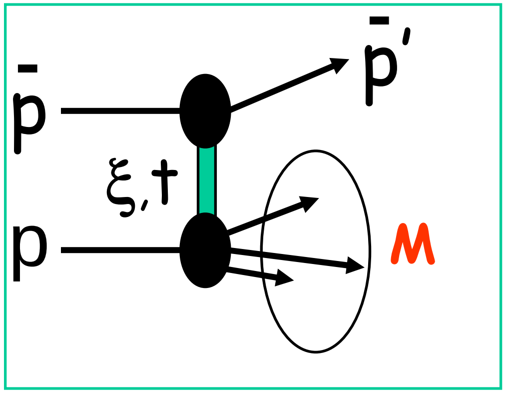
$$\frac{d\sigma}{dM^2} \propto \frac{s^{2\varepsilon \to 1}}{(M^2)^{1+\varepsilon}}$$

➔ Independent of s over 6 orders of magnitude in M^2!

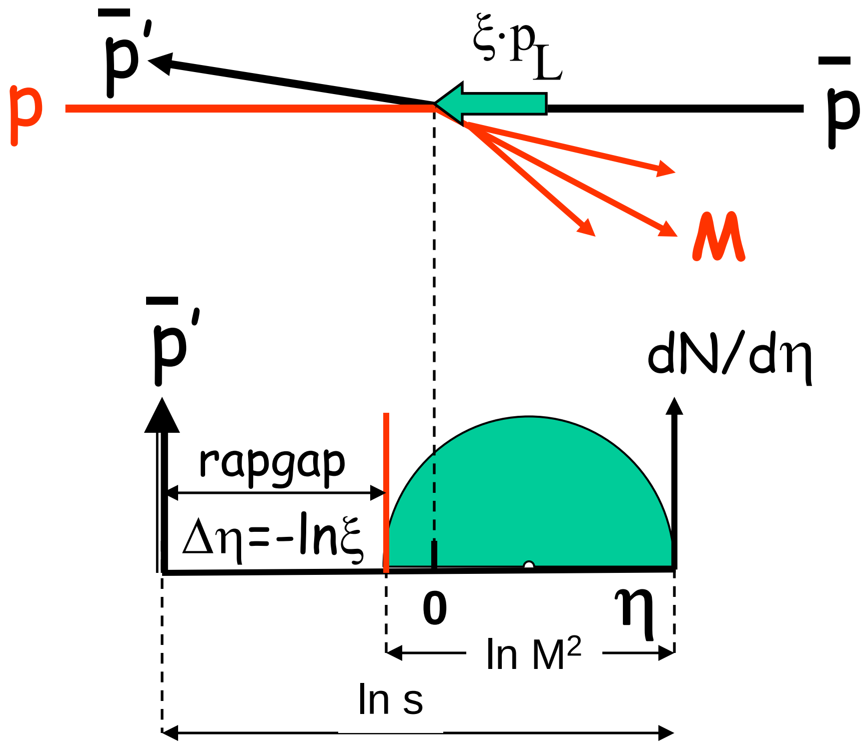
KG&JM, PRD 59 (1999) 114017



Factorization breaks down so as to ensure M^2 scaling!



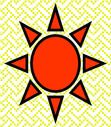
$$1 - x_L \equiv \xi = \frac{M^2}{s}$$

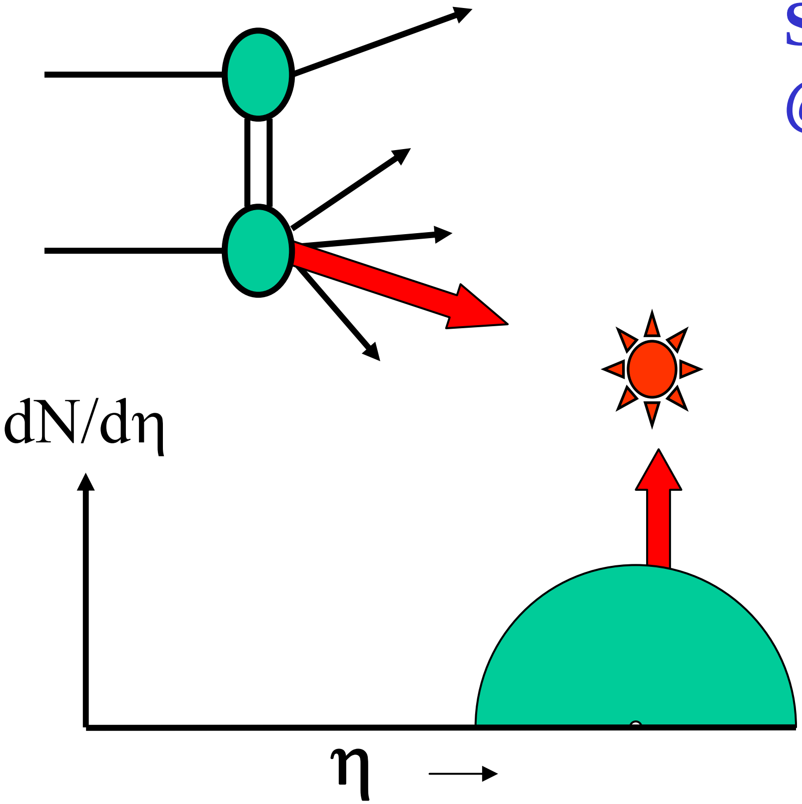


vacuum exchange ⇒

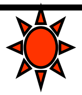
$$\left(\frac{d\sigma}{d\Delta\eta}\right)_{t=0} \approx \text{constant} \Rightarrow \frac{d\sigma}{d\xi} \propto \frac{1}{\xi} \Rightarrow \frac{d\sigma}{dM^2} \propto \frac{1}{M^2}$$

Hard diffractive fractions - Run I

$\bar{p}p \rightarrow ($  $+ X) + \text{gap}$



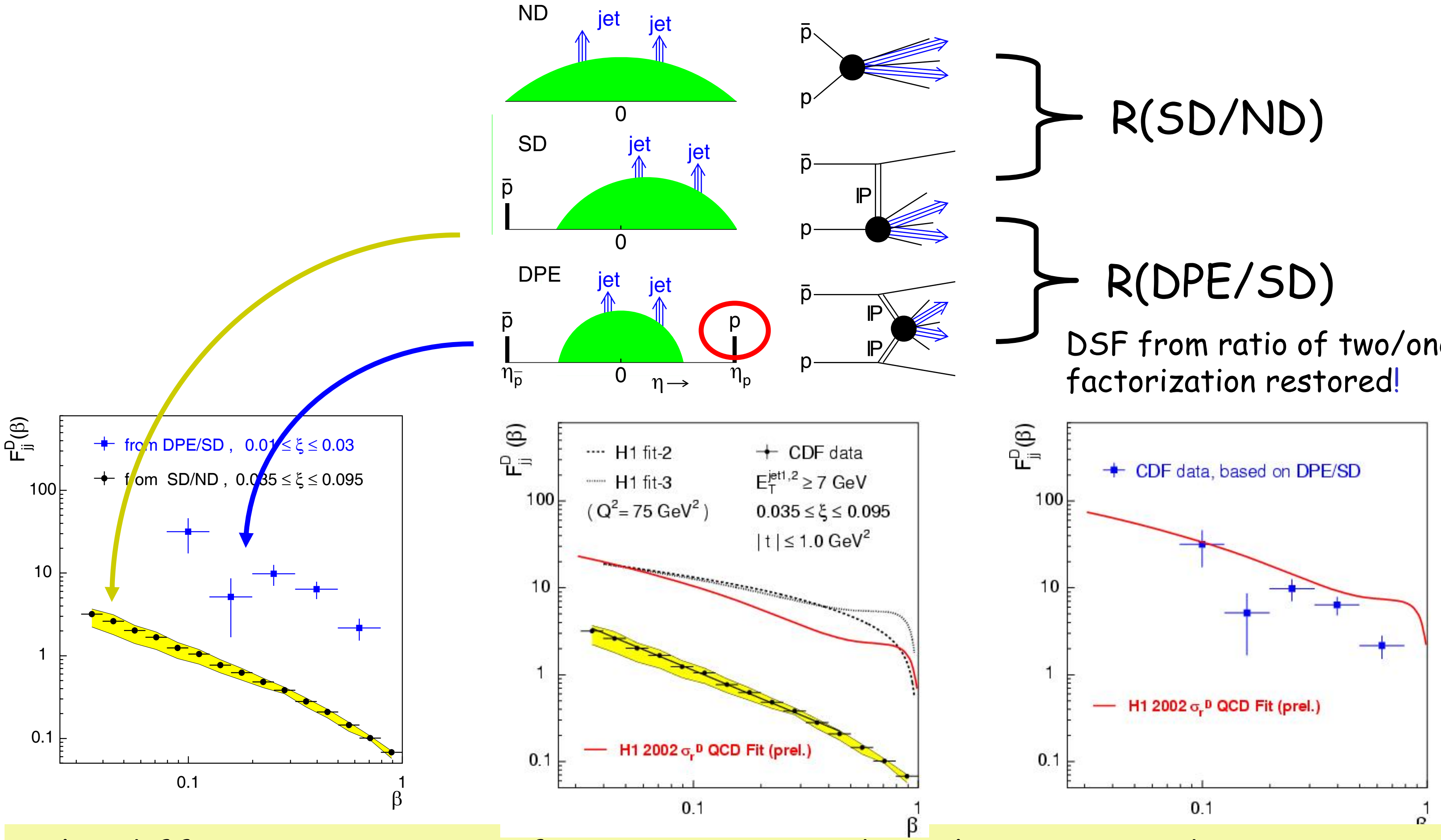
Fraction:
SD/ND ratio
@ 1800 GeV

	Fraction %
JJ	0.75 +/- 0.10
W	0.115 +/- 0.55
b	0.62 +/- 0.25
J/ψ	1.45 +/- 0.25

All fractions ~ 1%
(differences due to kinematics)

- ~ uniform suppression
- ~ FACTORIZATION ! !

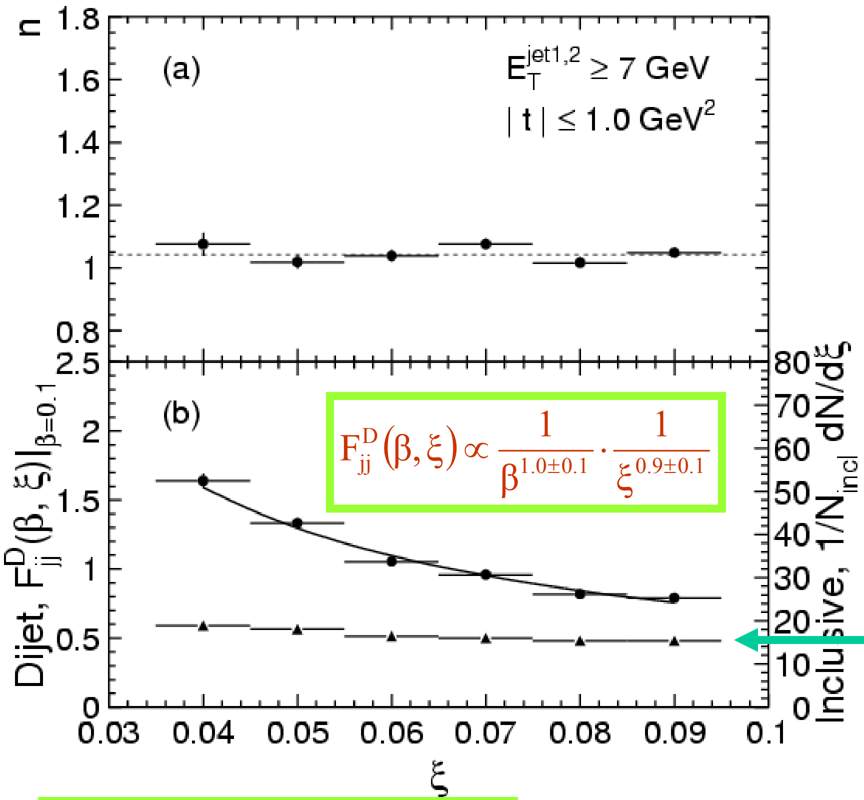
Multi-gap diffraction – Run I
➔ restoring factorization



DSF from ratio of two/one gap: factorization restored!

The diffractive structure function measured on the proton side in events with a leading antiproton is NOT suppressed relative to predictions based on DDIS

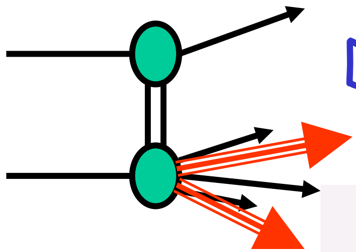
ξ & β dependence of F^D_{jj} - Run I



$$\frac{d\sigma_{incl}}{d\xi} \propto \text{constant}$$

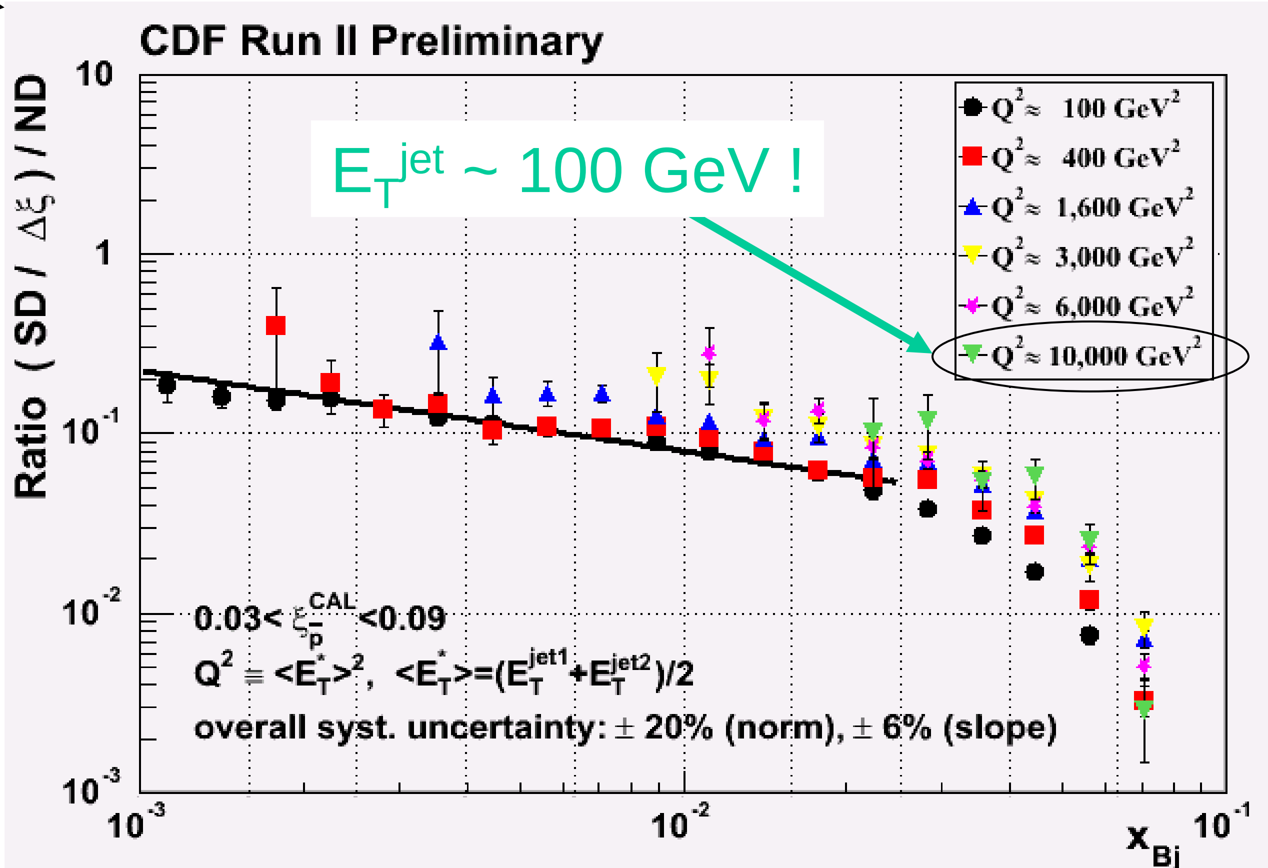
$$F^D_{jj}(\beta,\xi) \sim \frac{1}{\beta} \cdot \frac{1}{\xi}$$

Pomeron dominated



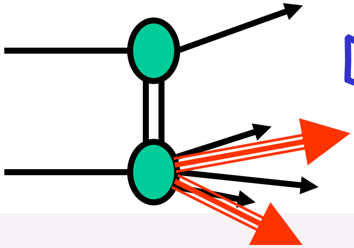
Diffractive structure function - Run II

Q^2 - dependence



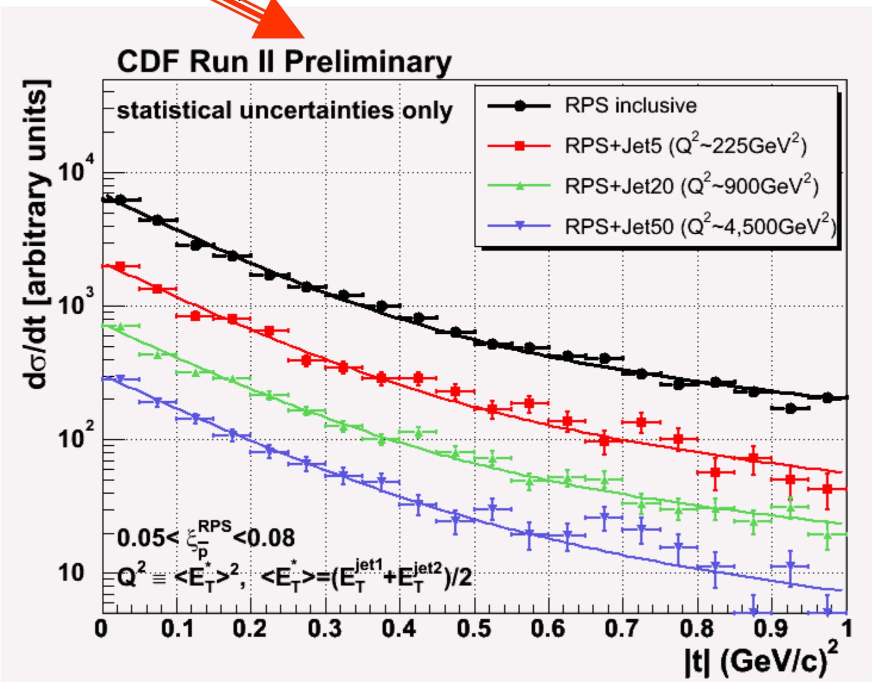
- Small Q^2 dependence in region $100 < Q^2 < 10\,000$ GeV^2 where $d\sigma^{SD}/dE_T$ & $d\sigma^{ND}/dE_T$ vary by a factor of $\sim 10^4$!

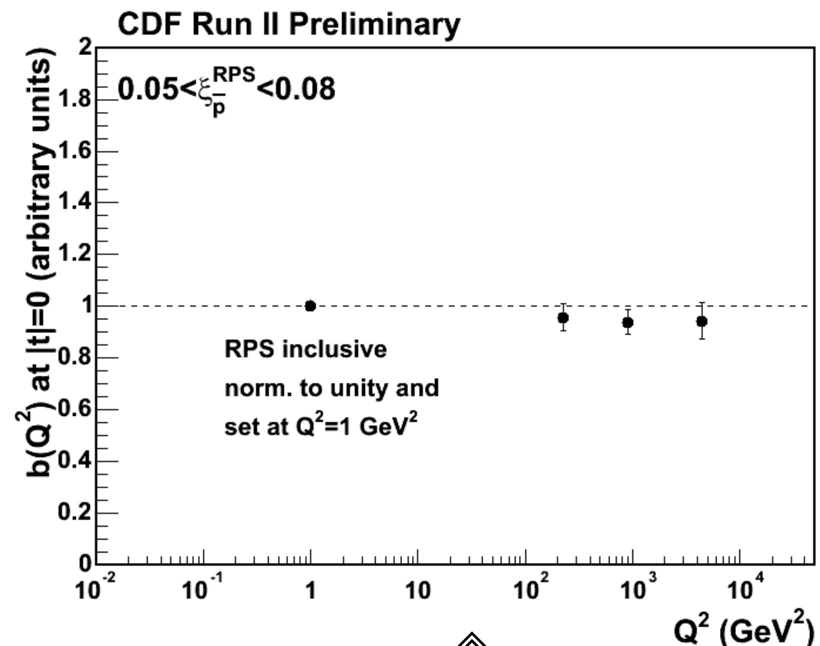
➔ The Pomeron evolves as the proton !



Diffractive structure function – Run II

t - dependence





Fit dσ/dt to a double exponential:

$$F = 0.9 \cdot e^{b_1 \cdot t} + 0.1 \cdot e^{b_2 \cdot t}$$

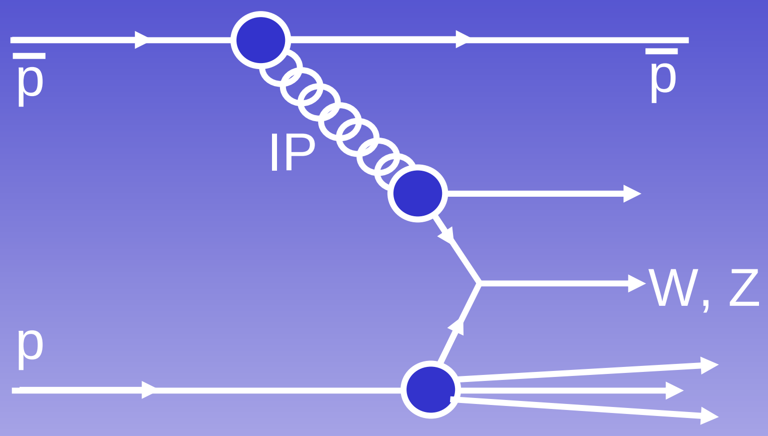
- No diffraction dips
- No Q2 dependence in slope from inclusive to Q^2~10^4 GeV^2

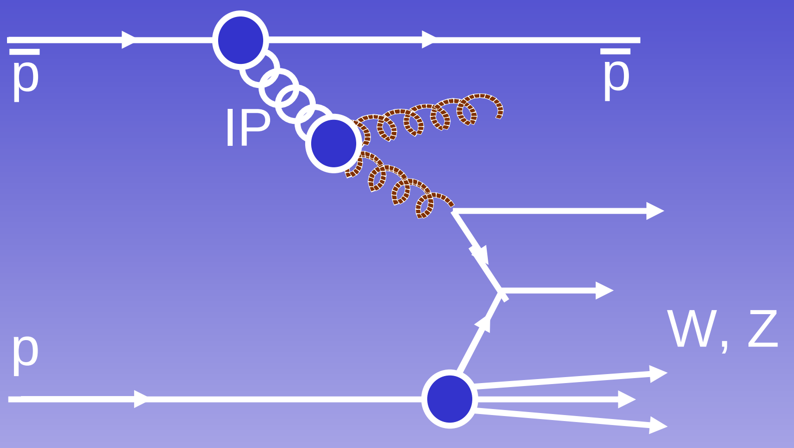
- Same slope over entire region of 0 < Q^2 < ~ 10 000 GeV^2!

Looks like…

… the underlying diffractive PDF on a hard scale is similar to the proton PDF except for small differences - presumably due to the requirement of combining with the soft PDF to form a spin 1 color singlet with vacuum quantum numbers.

Diffractive W/Z production





- Diffractive W production probes the quark content of the Pomeron
  - To leading order, the W is produced by a quark in the Pomeron

- Production by gluons is suppressed by a factor of α_S and can be distinguished from quark production by an associated jet

Diffractive W/Z - motivation

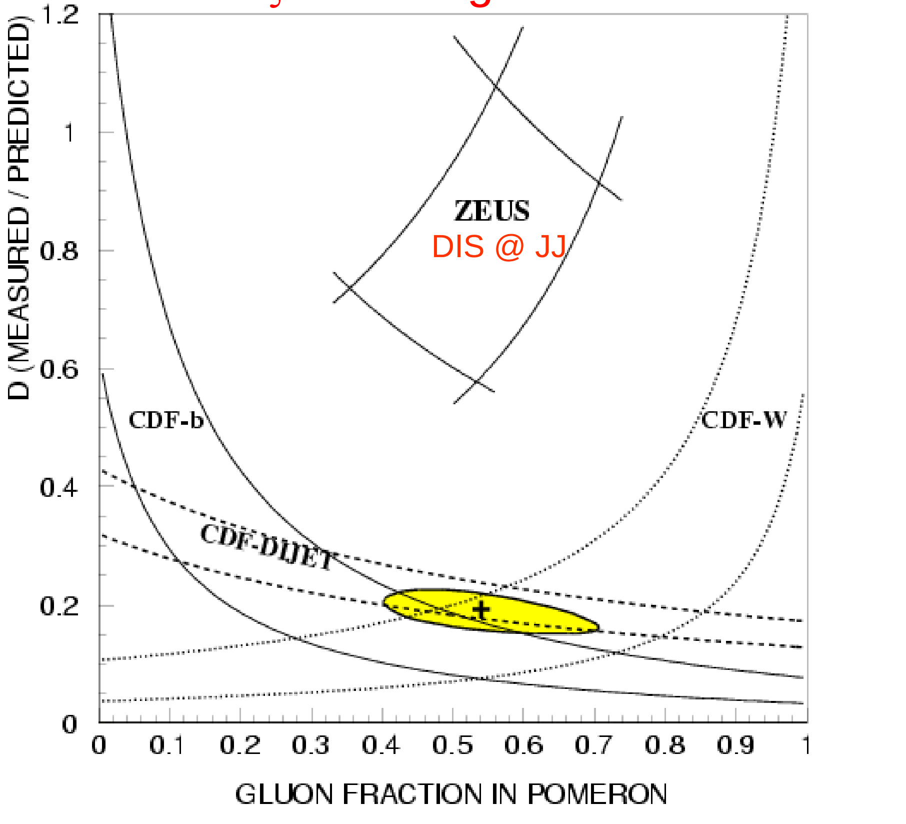
- **In Run I**, by combining diffractive dijet production with diffractive W production we determined the quark / gluon content of the Pomeron ===➔
- **In Run II,** we aim at determining the diffractive structure function for a more direct comparison with HERA.
- To accomplish this we use:
  - New forward detectors
  - New methodology
  - More data

Phys Rev Lett **78**, 2698 (1997)

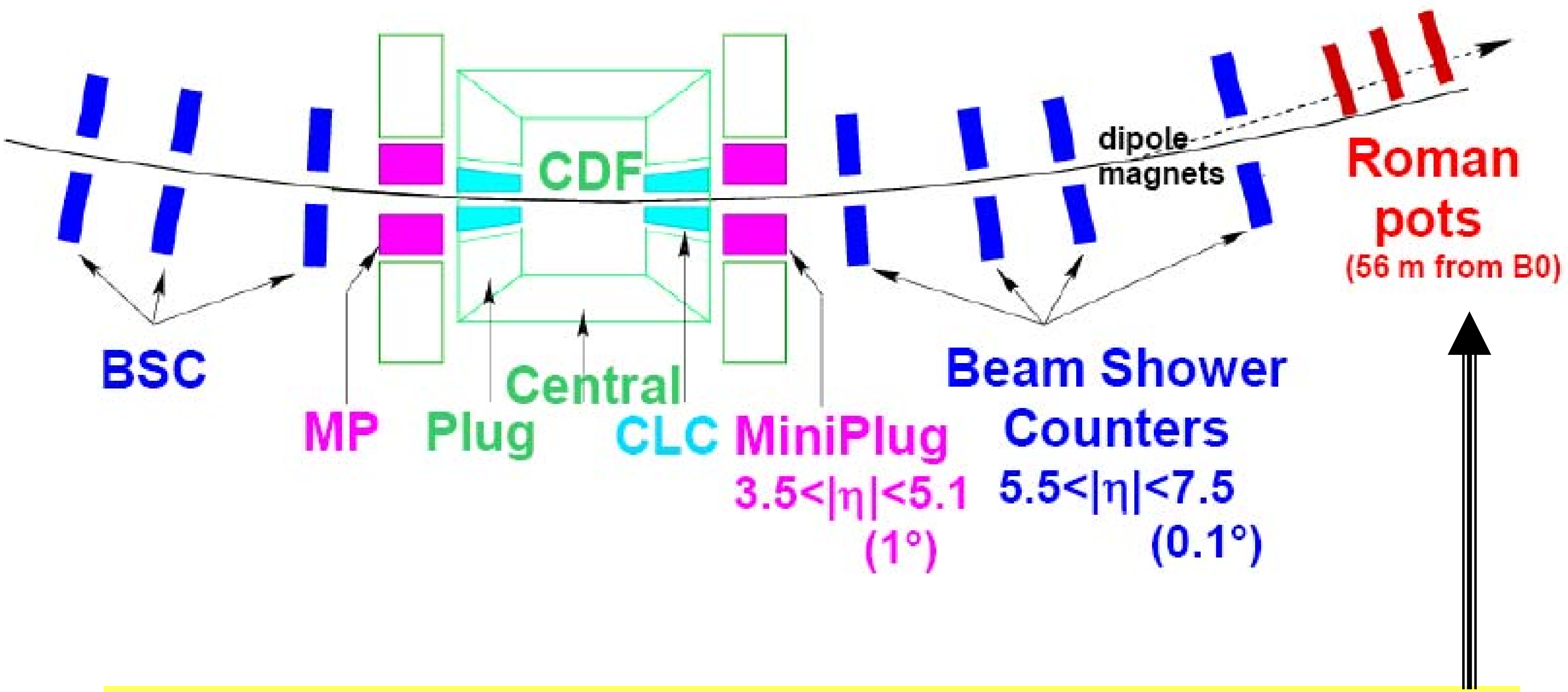
Fraction of W events due to SD

R^W=[1.15±0.51(stat)±0.20(syst)]%

for ξ<0.1 integrated over t

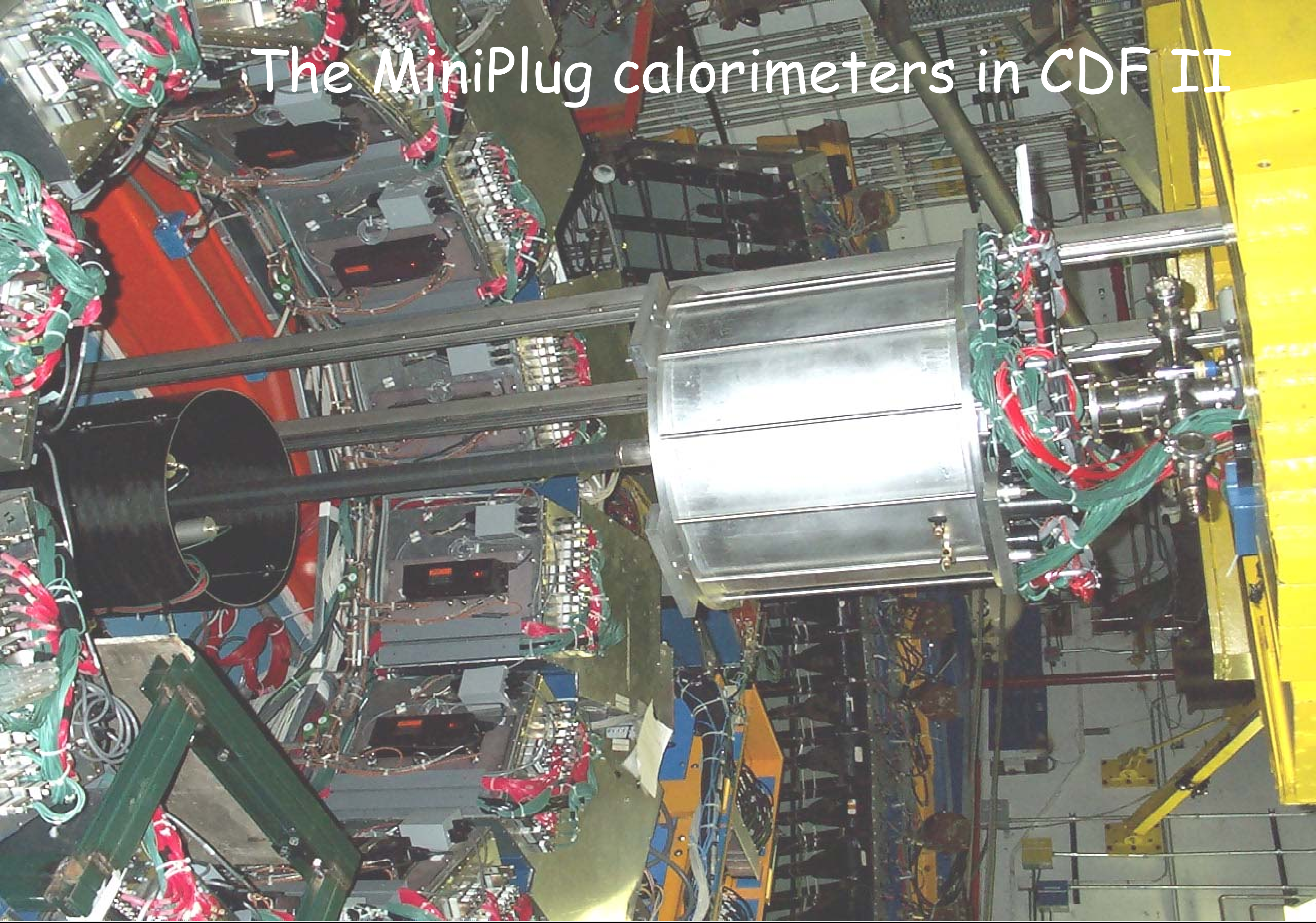


The CDF II detectors



RPS acceptance ~80% for $0.03 < \xi < 0.1$ and $|t| < 0.1$

The MiniPlug calorimeters in CDF II



Diffractive W/Z analysis

Using RPS information:

- No background from gaps due to multiplicity fluctuations
- No gap survival probability systematics
- The RPS provides accurate event-by-event ξ measurement
- Determine the full kinematics of diffractive W production by obtaining η_ν using the equation:

$$\xi^{RPS} - \xi^{cal} = \frac{\not{E}_T}{\sqrt{s}} e^{-\eta_\nu} \quad \text{where} \quad \xi^{cal} = \sum_{towers} \frac{E_T}{\sqrt{s}} e^{-\eta}$$

This allows the determination of:

- W mass
- x_{Bj}
- Diffractive structure function

W/Z selection requirements

Standard W/Z selection

$E_T^e (p_T^\mu > 25$ GeV

$\not{M}_T > 25$ GeV

$40 < M_T^W < 120$ GeV

$|Z_{vtx}| < 60$ cm

$E_T^{e1} (p_T^{\mu 1} > 25$ GeV

$E_T^{e2} (p_T^{\mu 2} > 25$ GeV

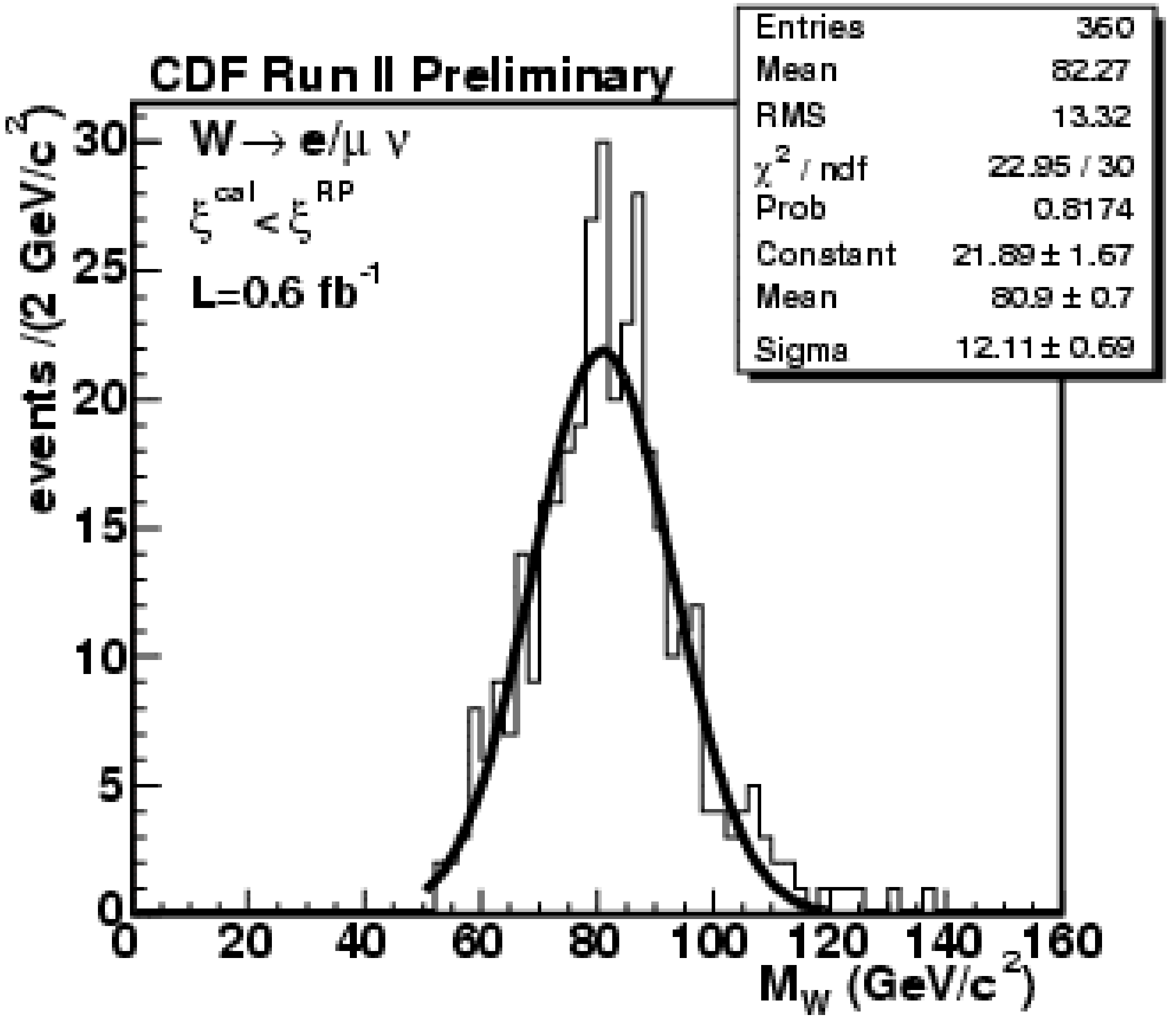
$66 < M^Z < 116$ GeV

$|Z_{vtx}| < 60$ cm

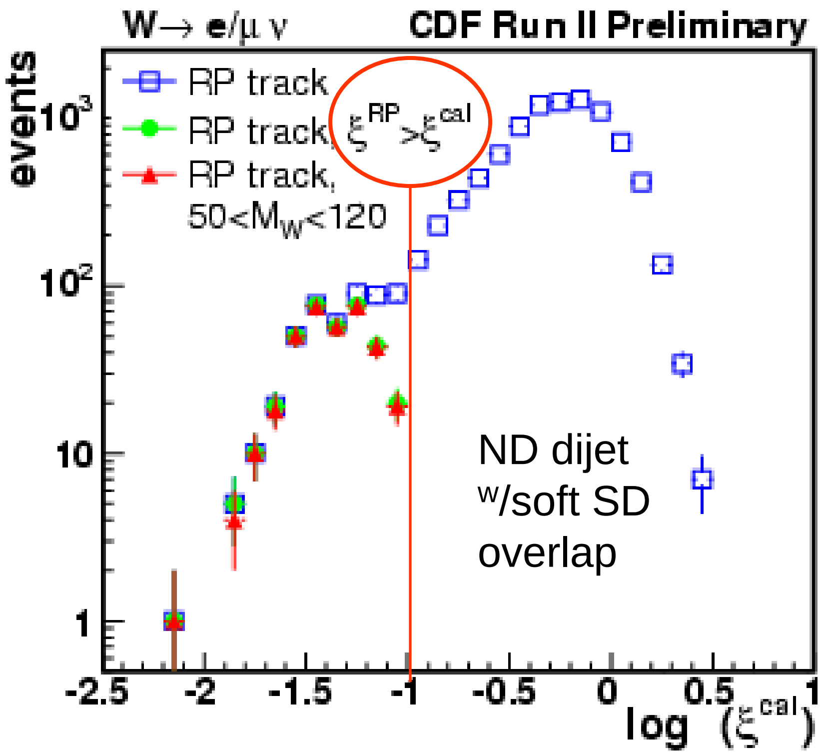
Diffractive W/Z selection

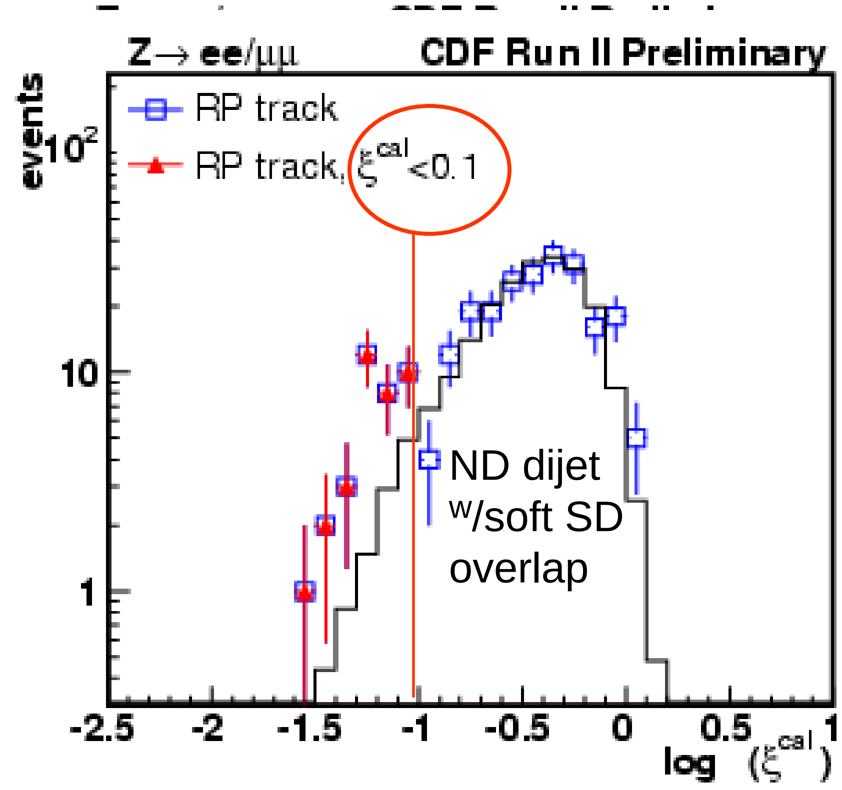
- RPS trigger counters – require MIP
- RPS track - $0.03 < \xi < 0.10$, $|t| < 1\,\text{GeV}^2$
- W➔ $50 < M_W(\xi^{RPS}, \xi^{cal}) < 120\ \text{GeV}^2$
- Z ➔ $\xi^{cal} < 0.1$

Reconstructed diffractive W mass



Rejection of multiple interaction events





Diffractive W/Z results

R^W (0.03 < ξ < 0.10, |t|<1)= [0.97 ± 0.05(stat) ± 0.11(syst)]%

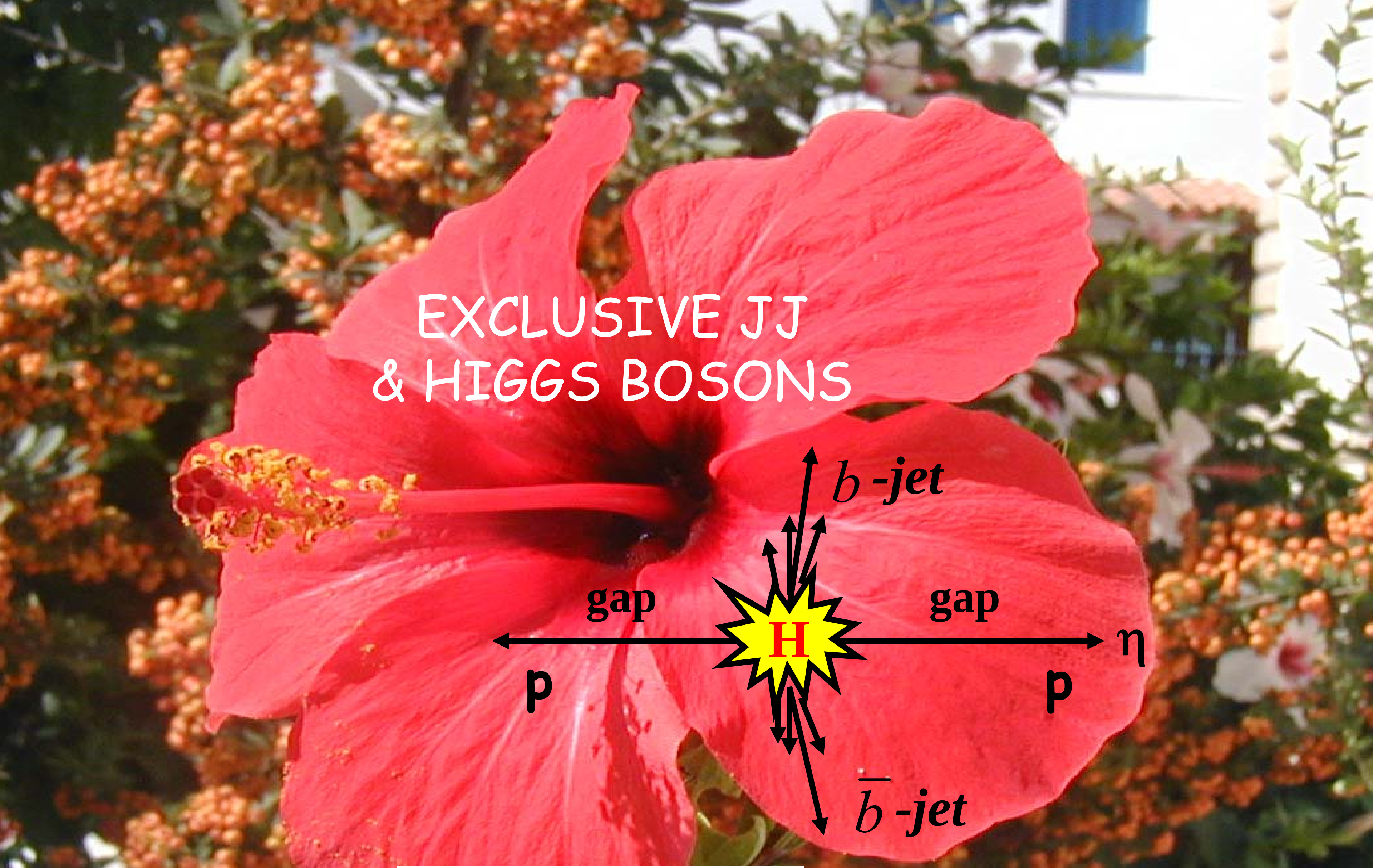
Run I: R^W (ξ<0.1)=[1.15±0.55] % ➔ **0.97±0.47 %** in **0.03 < ξ < 0.10 & |t|<1**

R^Z (0.03 < x < 0.10, |t|<1)= [0.85 ± 0.20(stat) ± 0.11(syst)]%

CDF/DØ Comparison – Run I (ξ < 0.1)

CDF PRL 78, 2698 (1997)	DØ Phys Lett B **574**, 169 (2003)
R^W=[1.15±0.51(stat)±0.20(syst)]%	R^W=[5.1±0.51(stat)±0.20(syst)]%
gap acceptance A^{gap}=0.81	gap acceptance A^{gap}=(0.21±4)%
Uncorrected for A^{gap}	Uncorrected for A^{gap}
R^W=(0.93±0.44)%	R^W=[0.89+0.19-0.17]%
	R^Z=[1.44+0.61-0.52]%

EXCLUSIVE JJ & HIGGS BOSONS



$M_H^2 = (p + \bar{p} - p' - \bar{p}')^2$

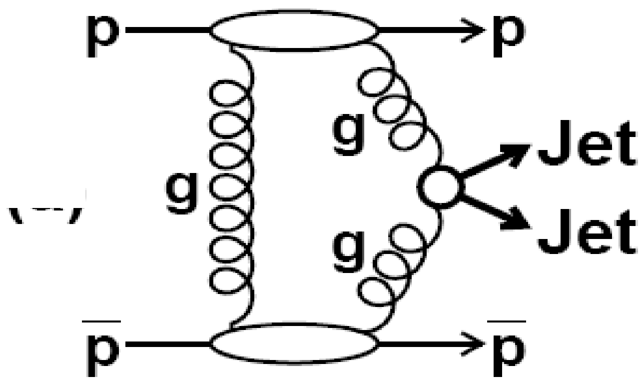
→ ΔM~(1-2) GeV

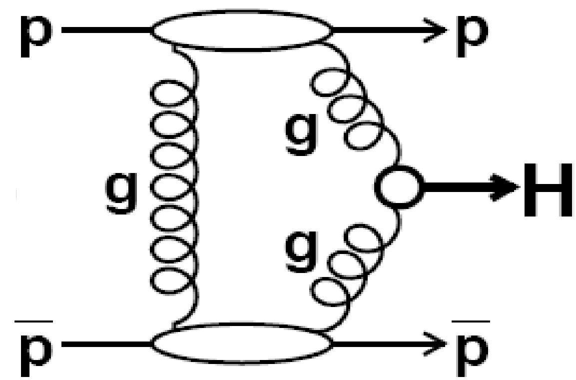
Determine spin of H

Exclusive di-jet and Higg production

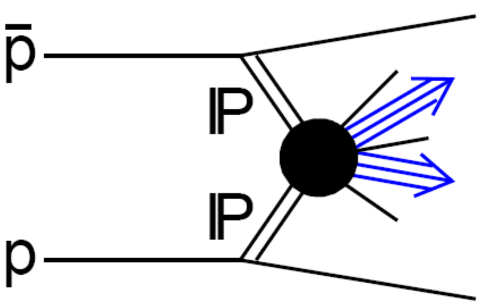
URL: http://link.aps.org/abstract/PRD/v77/e052004 Phys. Rev. D 77, 052004

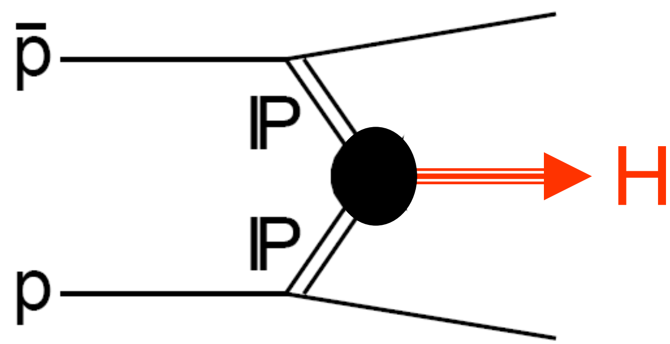
ExHuME





DPEMC

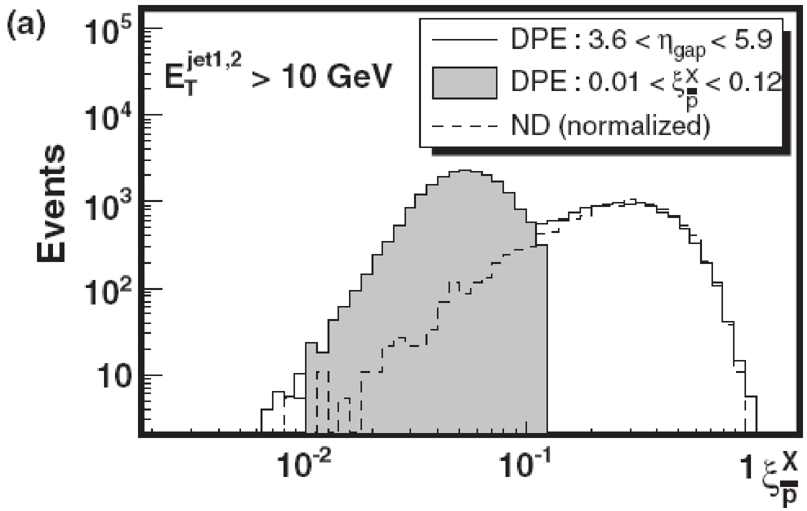


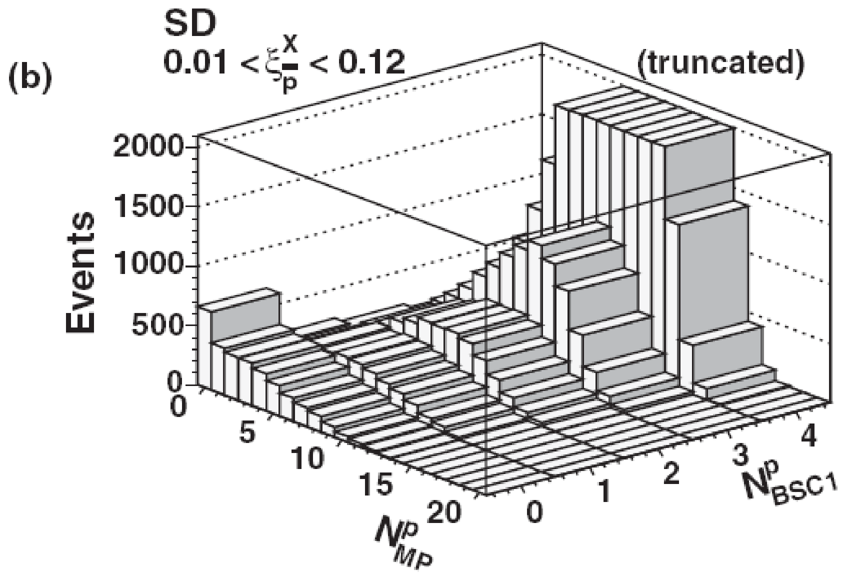


The DPE data sample

$$\xi_{pbar}^{CAL} = \sum_{towers} \frac{E_T}{\sqrt{s}} e^{-\eta}$$

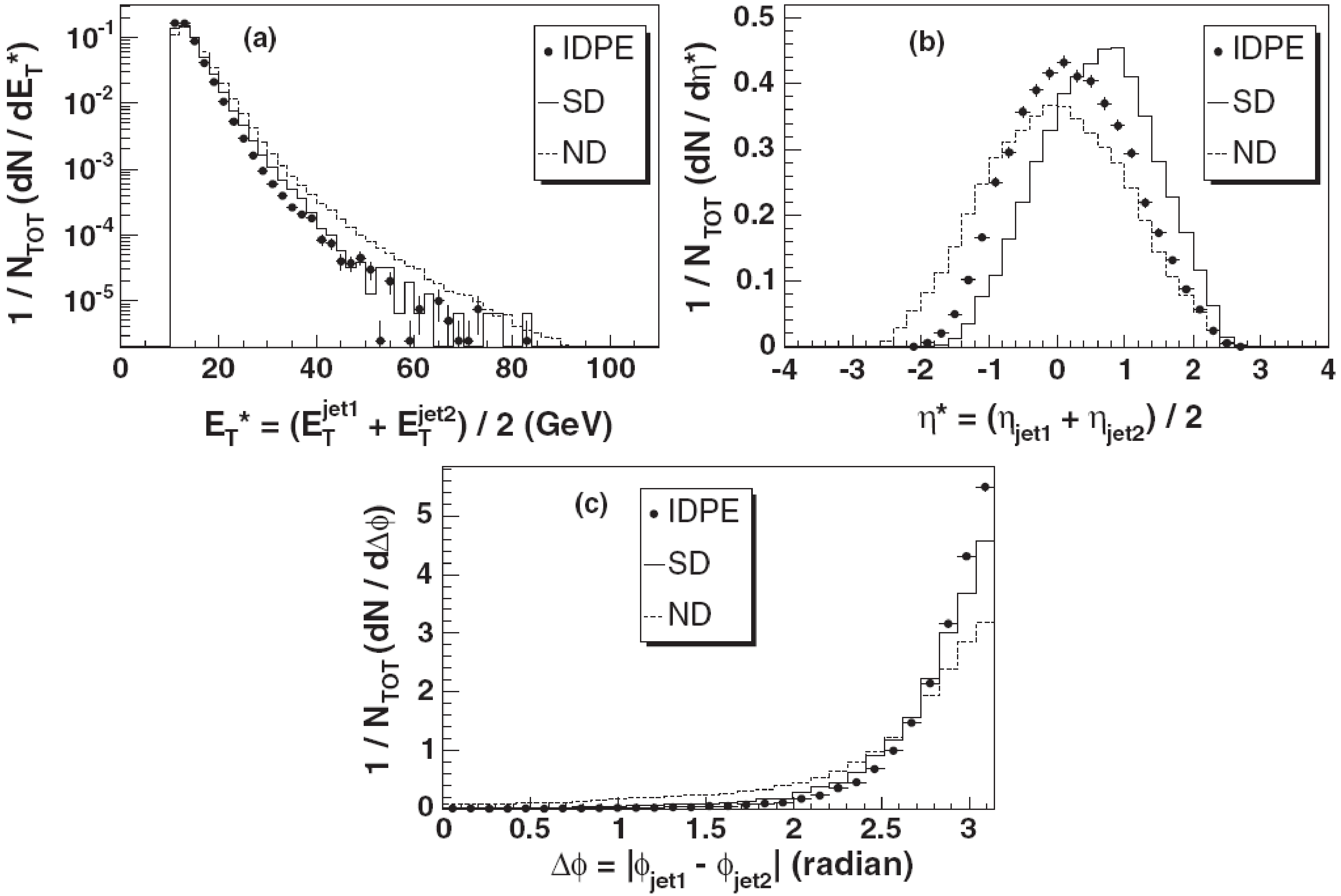
← Fractional momentum loss of anti-proton obtained from CDF II calorimeter tower E_T and η





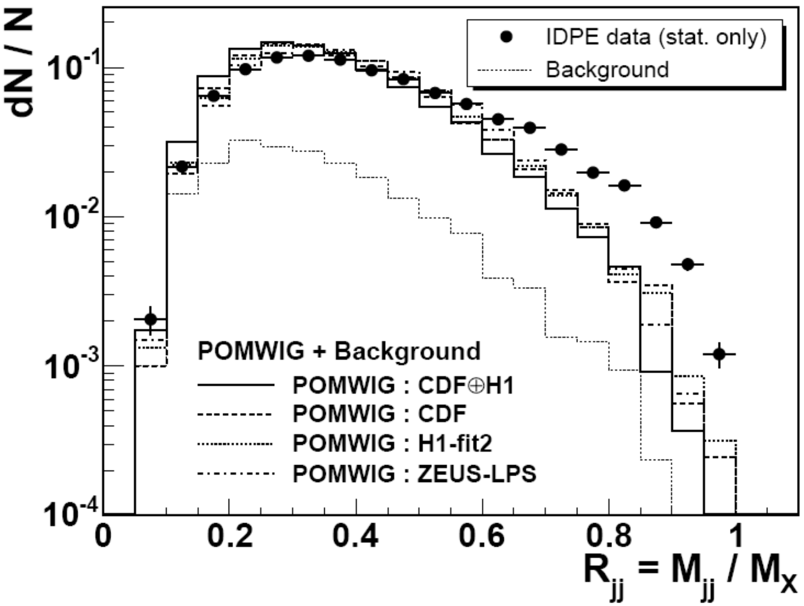
"DPE event sample" : $0.01<\xi^X<0.12$ → used to validate kinematic properties of di-jet events

Kinematic distributions

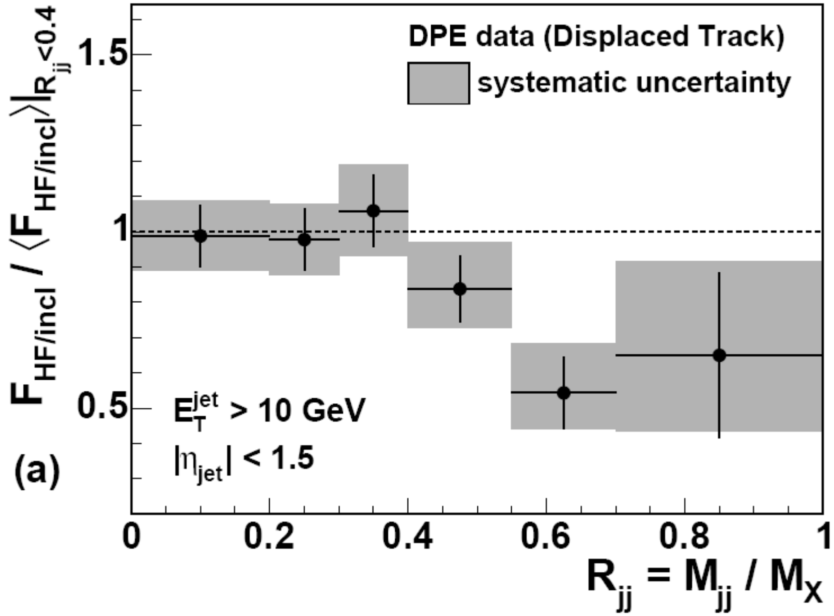


Exclusive di-jet signal

inclusive di-jet mass fraction



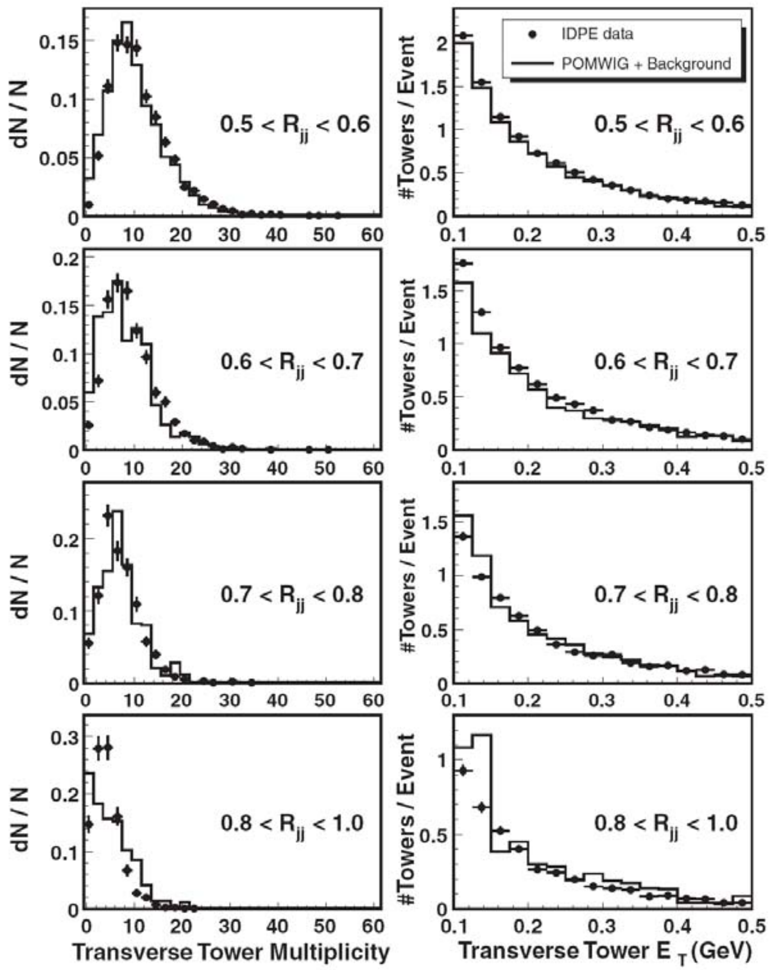
b-jet di-jet mass fraction



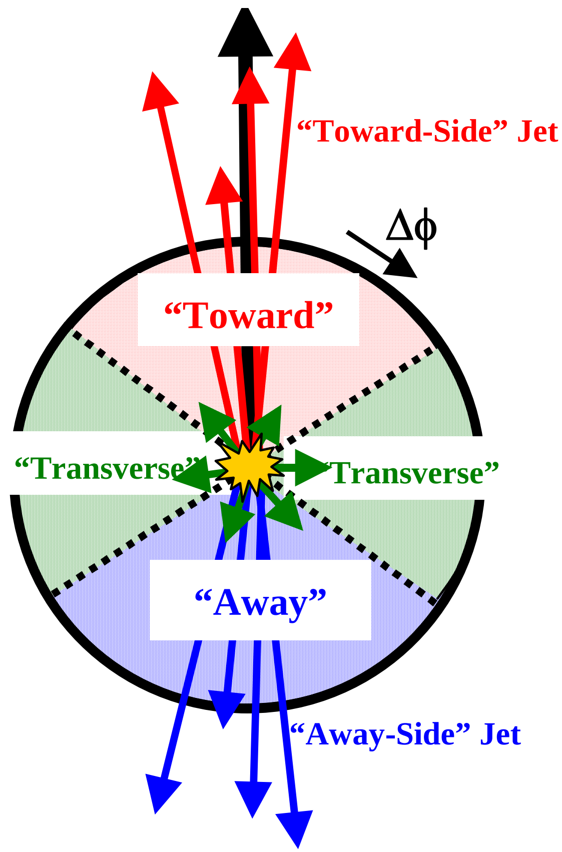
Excess observed over POMWIG MC prediction at large Rjj

Exclusive b-jets are suppressed as expected (J_Z= 0 selection rule)

Underlying Event (UE)

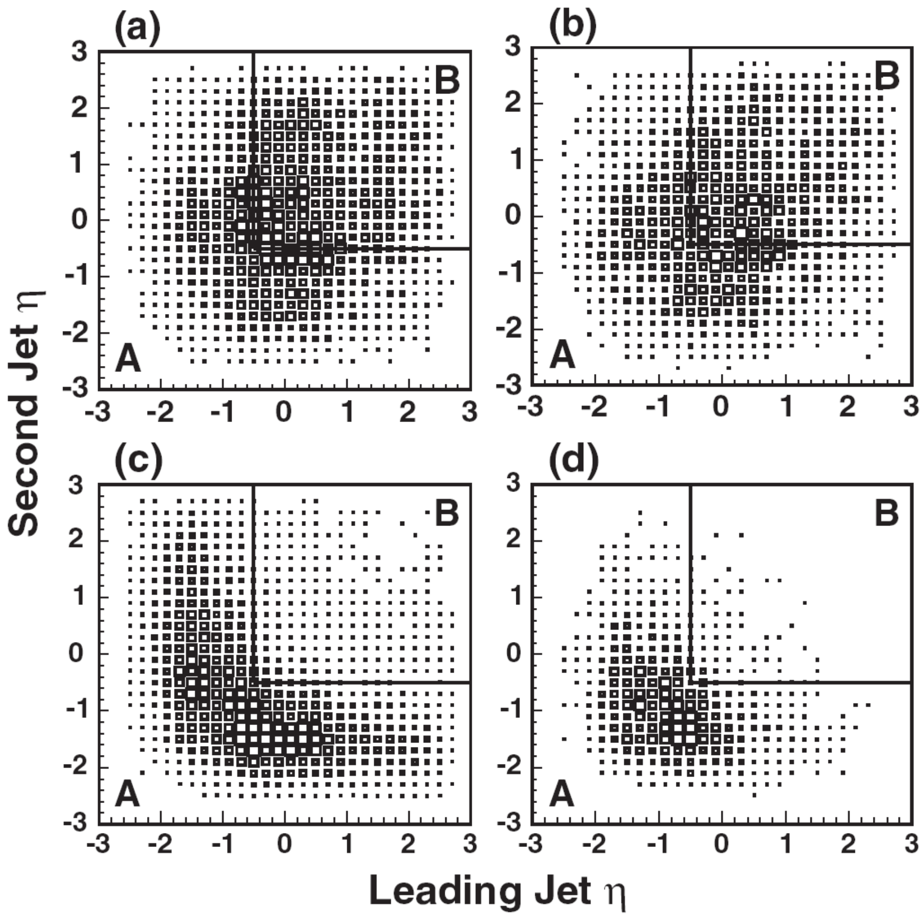


Is it modeled correctly?



The data and POMWIG+Background distributions in the transverse $\Delta\phi$-region relative to the di-jet axis agree, indicating that the UE is correctly modeled.

Jet1 vs. Jet2: signal and background regions

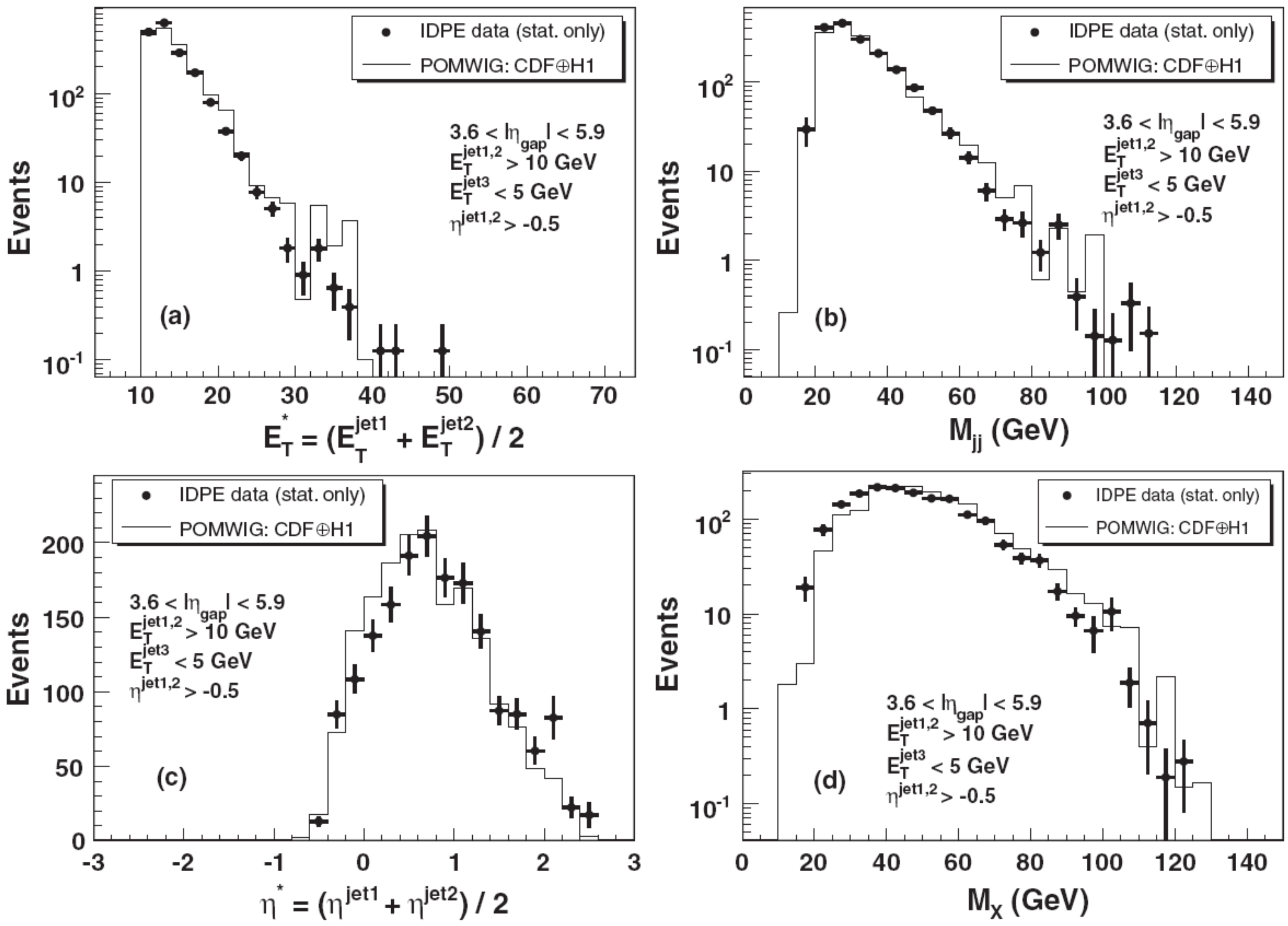


DATA

A: signal region
B: background region

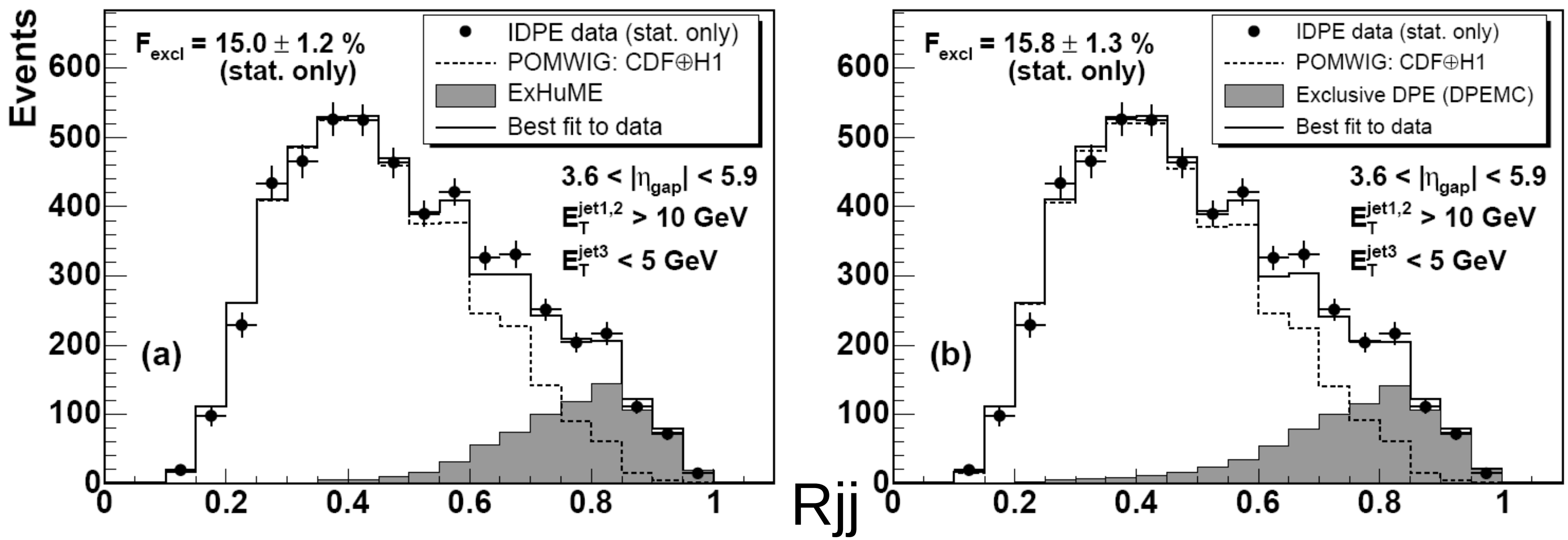
POMWIG

Background region



Inclusive DPE ^{W}/LRG$_p$: data vs. MC

ExHuME ←exclusive MC models→ DPEMC



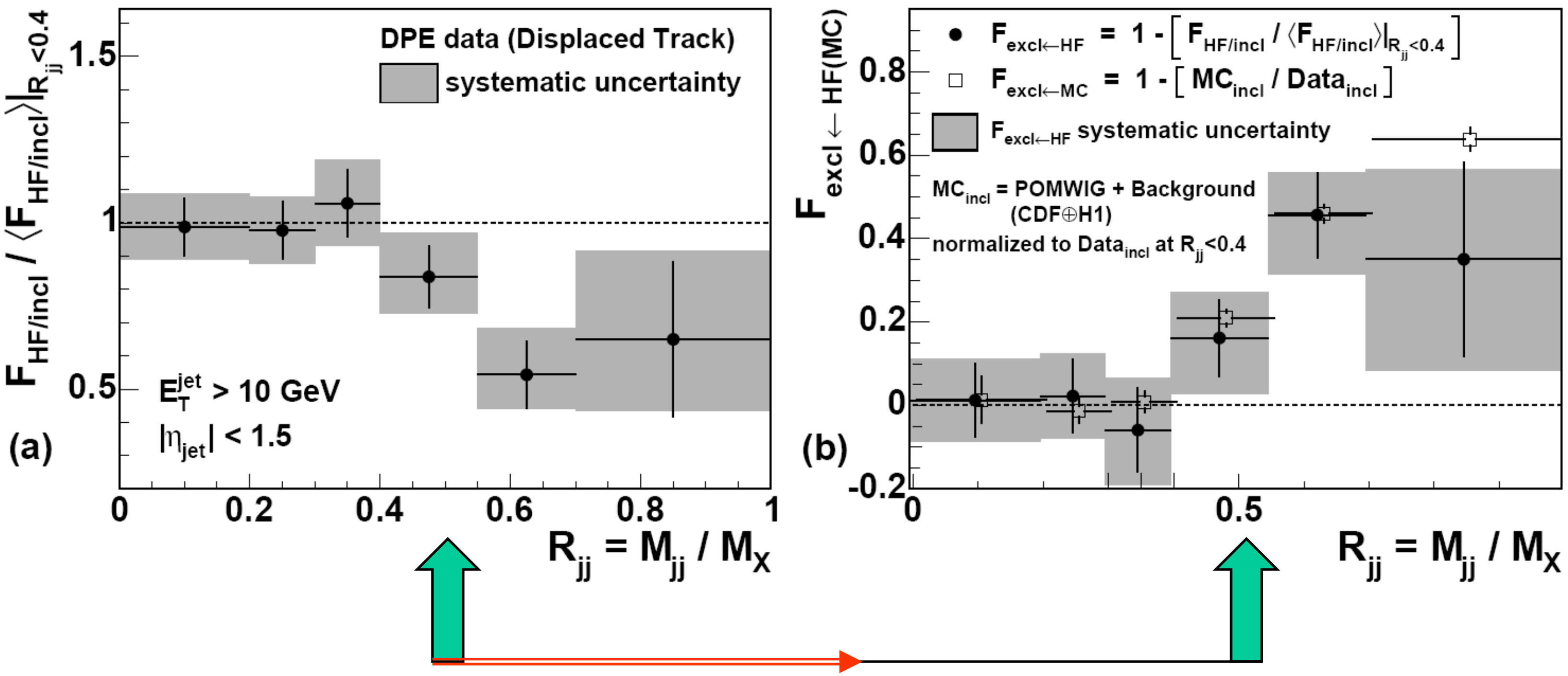
ExHuME (KMR): gg→gg process (based on LO pQCD)

DPEMC: exclusive DPE MC based on Regge theory

Shape of excess of events at high R_{jj}
is well described by both ExHuME & DPEMC – but…

Heavy flavor suppression vs. inclusive signal

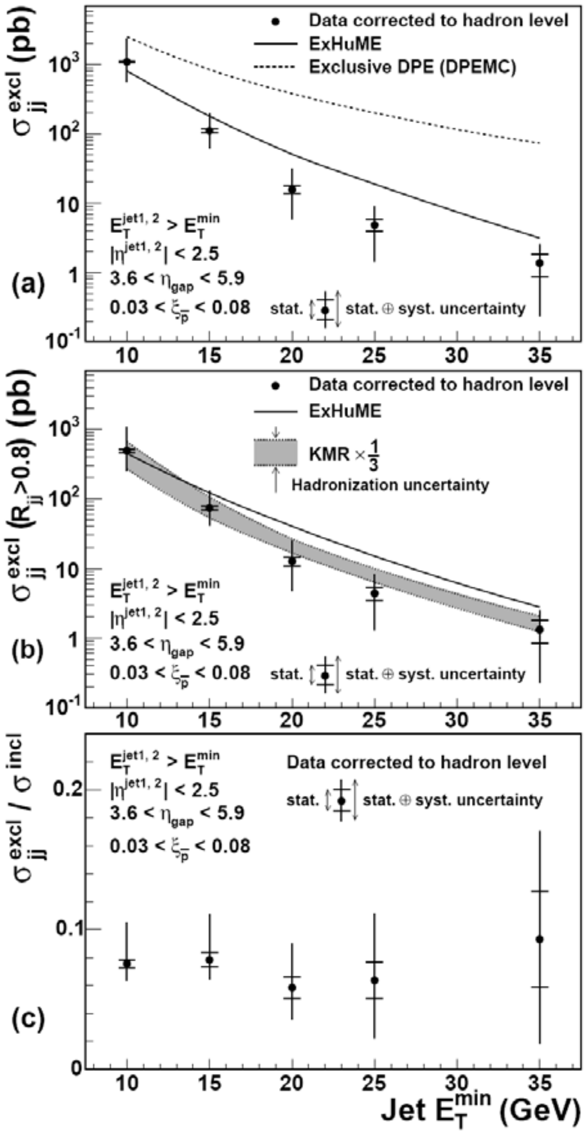
HF suppression | HF suppression vs. Incl



Invert HF vertically and compare with 1-MC/DATA

➔ good agreement observed

ExHuME vs. DPEMC and vs. data

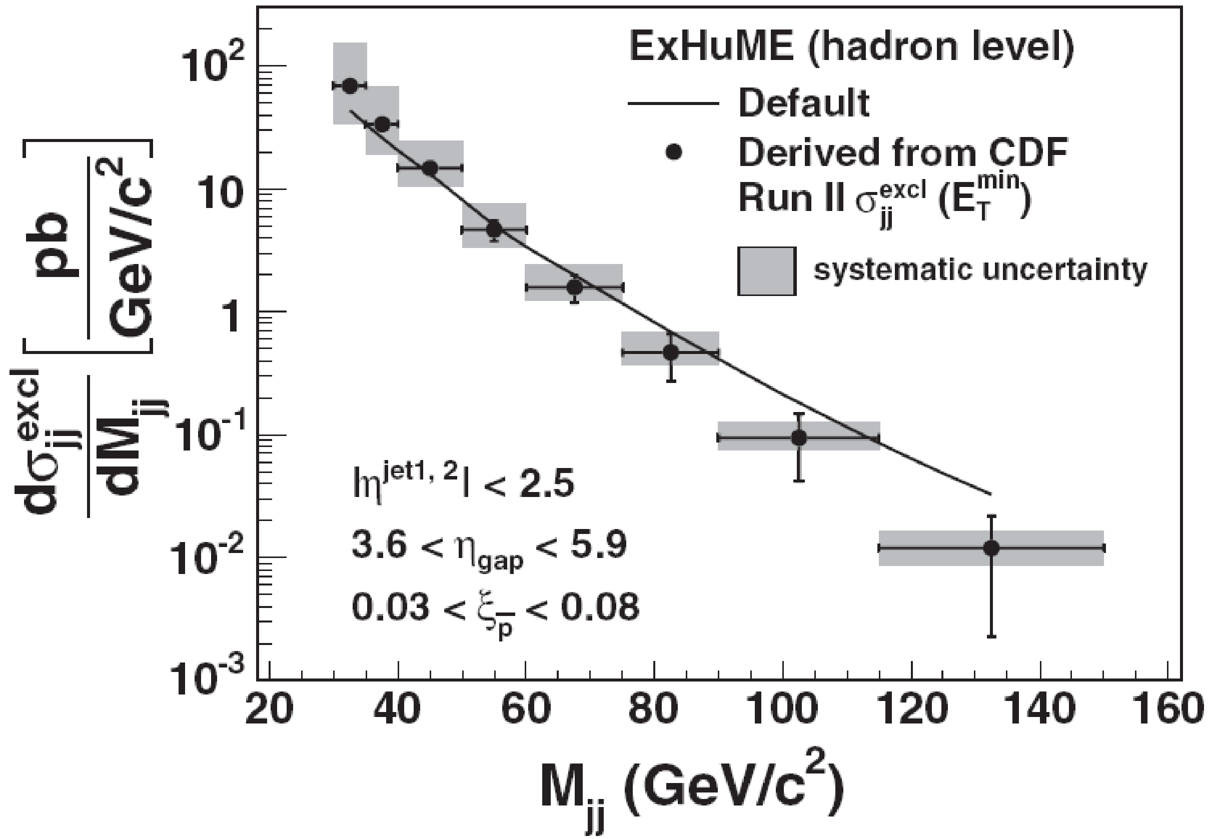


- Measured x-sections favor ExHuME

- KMR x 1/3 agrees with data
  - ➔ Within theoretical uncertainty of +/- factor of 3

- $\sigma_{jj}^{excl}/\sigma^{incl}$ approx. independent of E_T^{min}

Exclusive di-jet x-section vs. M_{jj}



line: ExHuME hadron-level exclusive di-jet cross section vs. di-jet mass

points: derived from CDF excl. di-jet x-sections using ExHuME

Stat. and syst. errors are propagated from measured cross section uncertainties using M_{jj} distribution shapes of ExHuME generated data.

DIJET

SUMMARY

HIGGS ?

W/Z

- Introduction
  - diffractive PDF looks like proton PDF
- Diffractive W/Z – RPS data
  - W diffractive fraction in agreement with Run I
  - W/Z diffractive fractions equal within error
  - New techniques developed to enable extracting the diffractive structure function in W production
- Exclusive di-jet/(Higgs?) production
  - Results favor ExHuME over DPEMC
    Phys. Rev. D **77**, 052004 (2008)

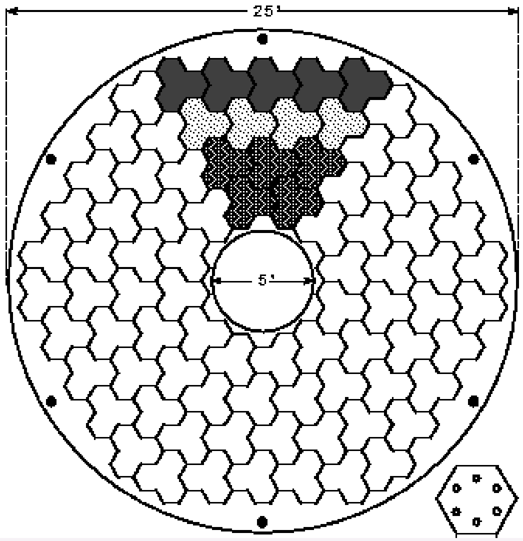
BACKUP

Measurements w/ the MiniPlugs

Dynamic Alignment of RPS Detectors

E^T_{jet} Calibration

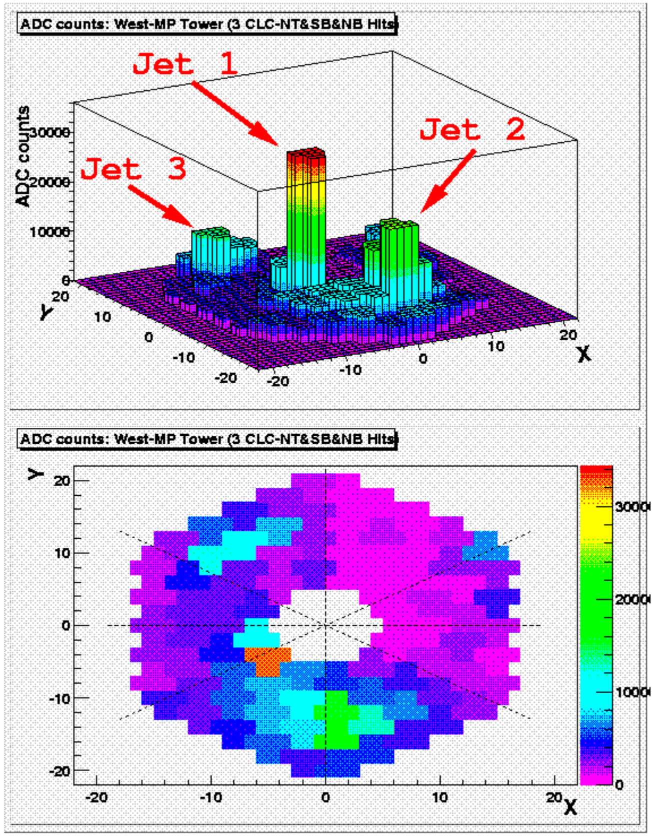
Measurements ^{w}/the MiniPlugs

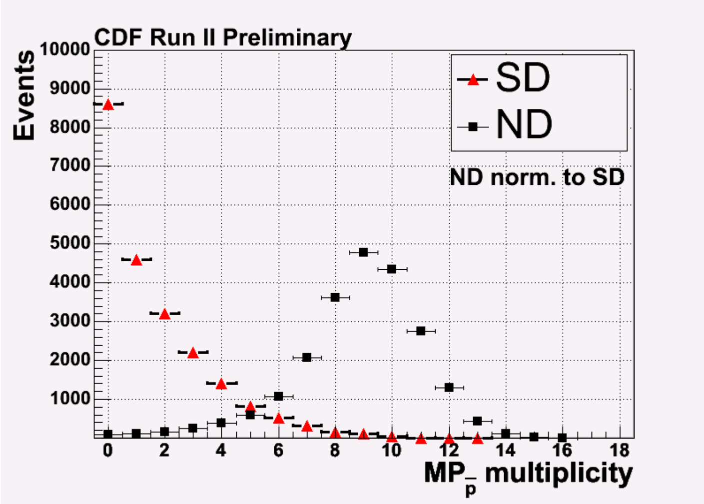


MP TOWER STRUCTURE

MULTIPLICITY @ POSITION

ENERGY





Multiplicity of SD and ND events

$$\xi^{CAL} = \frac{\Sigma_i E_T^i e^{-\eta_i}}{\sqrt{s}}$$

NIM A 430 (1999)

NIM A 496 (2003)

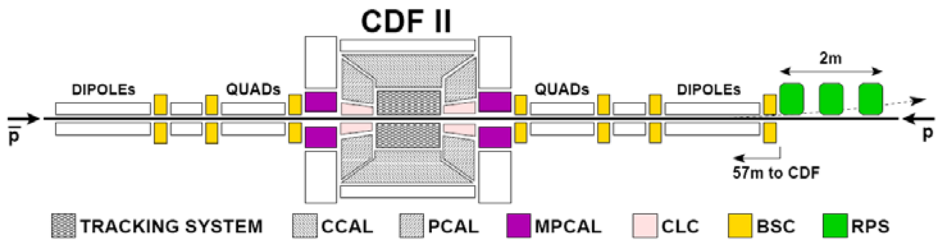
NIM A 518 (2004)

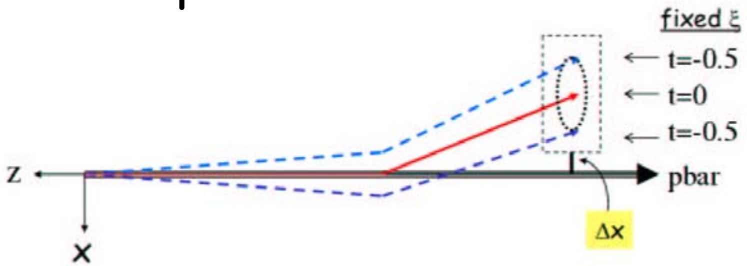
ADC counts in MiniPlug towers in a pbar-p event at 1960 GeV.

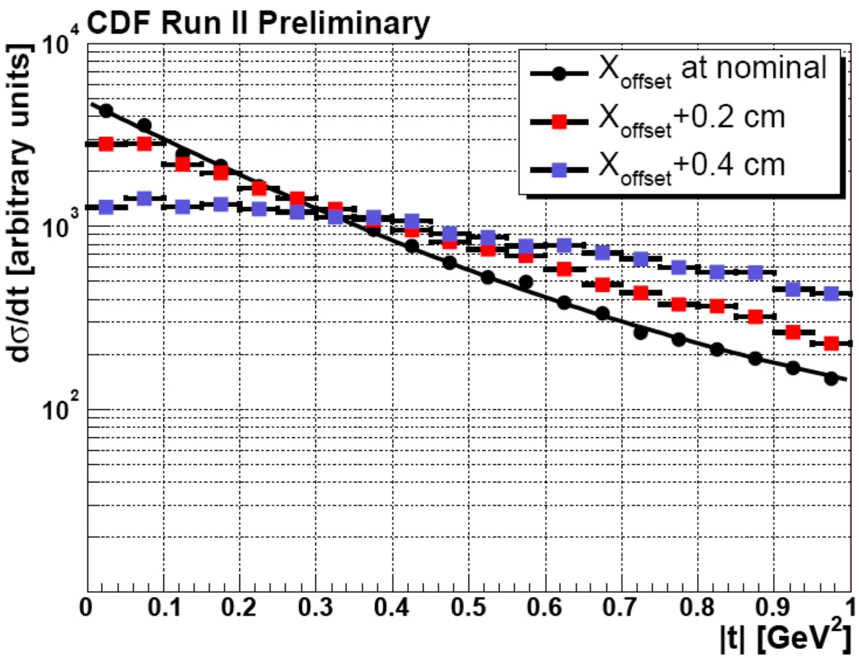
- **"jet" indicates an energy cluster and may be just a hadron.**
- **1000 counts ~ 1 GeV**

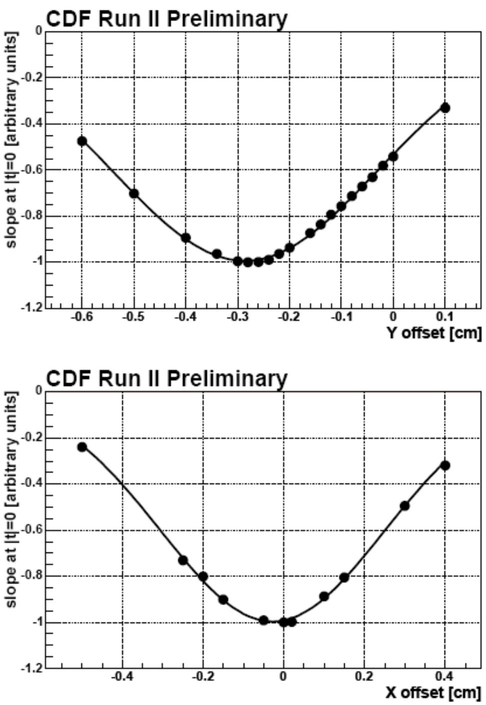
Dynamic alignment of RPS detectors

Method: iteratively adjust the RPS X and Y offsets from the nominal beam axis until a maximum in the b-slope is obtained @ t=0.









Limiting factors

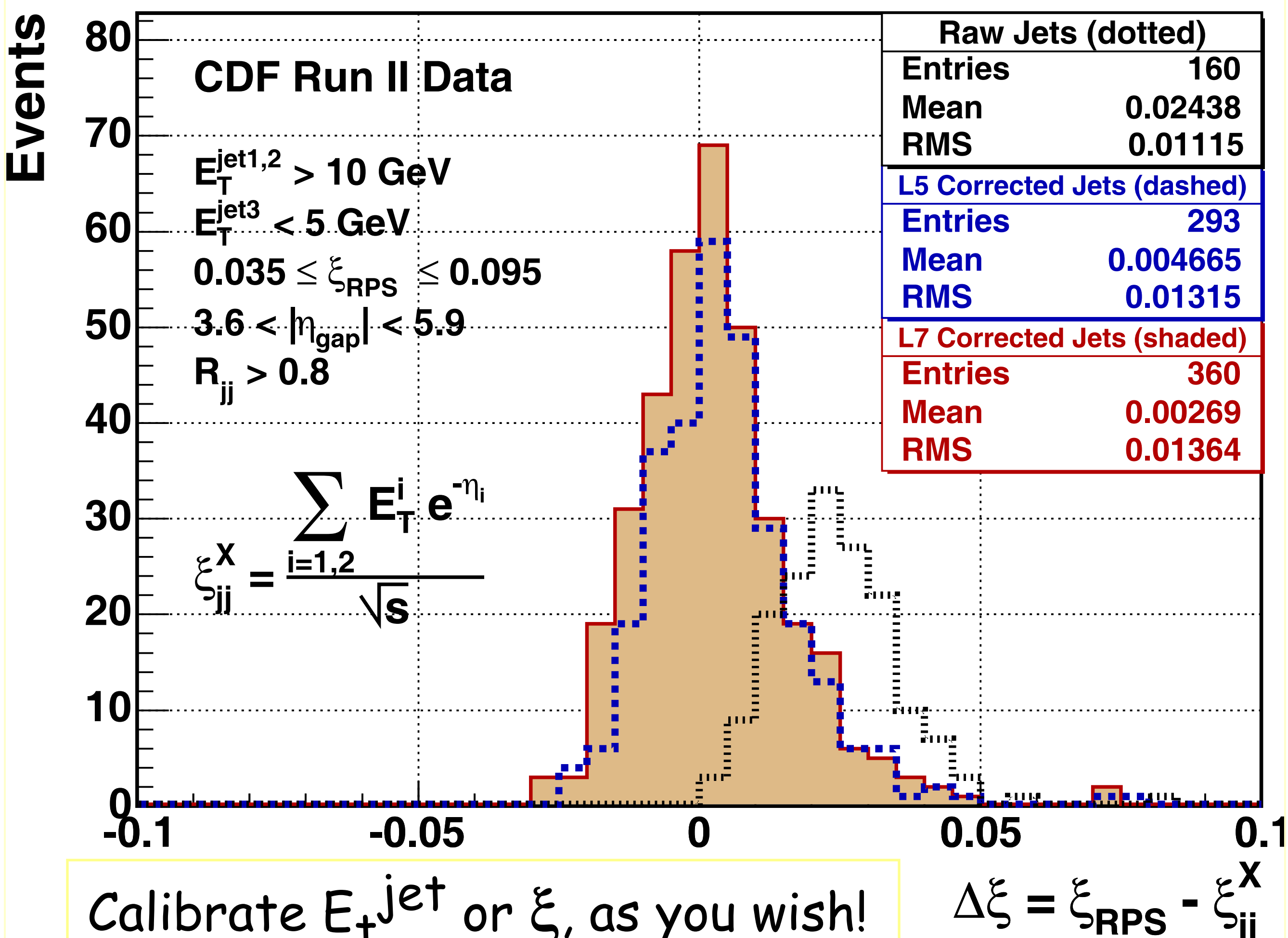
1-statistics
2-beam size
3-beam jitter

@ CDF
w/lowlum data

$\pm 30\ \mu m$

E_T^{jet} calibration

➔use RPS information to check jet energy corrections🡐



Calibrate E_T^{jet} or ξ, as you wish!


thank you